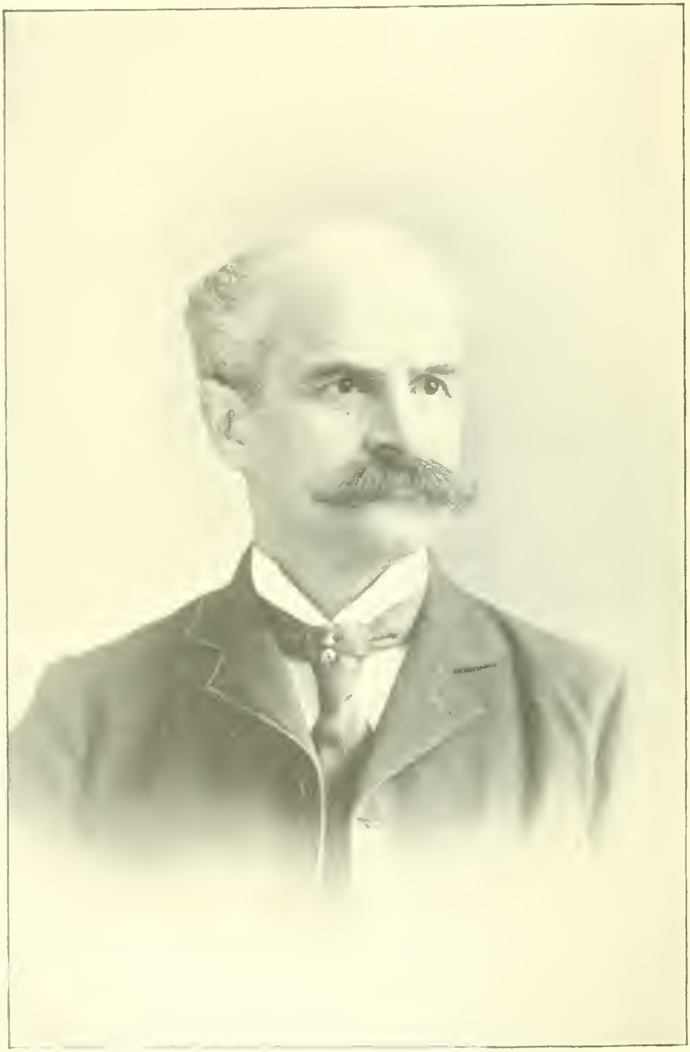


Albert F. Noyes

President of the Boston Society of Civil Engineers,
from March, 1895, to March, 1896.

JOURNAL

OF THE

Association of Engineering Societies.

Boston. Cleveland, Minneapolis, St Louis.
Montana. St. Paul. Denver.
Virginia. Pacific Coast. Detroit.

CONTENTS AND INDEX.

VOLUME XVIII.

January to June, 1897.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

John C. Trautwine, Jr., *Secretary*, 257 S. Fourth Street, Philadelphia.

CONTENTS

VOL. XVIII. January–June, 1897.

For alphabetical index, see page v

No. 1. JANUARY.

No. 2. FEBRUARY.

No. 3. MARCH.

No. 4. APRIL.

No. 5. MAY.

No. 6. JUNE.

INDEX.

VOL. XVIII, January–June, 1897.

The six numbers were dated as follows:

No. 1, January.	No. 3, March.	No. 5, May.
No. 2, February.	No. 4, April.	No. 6, June.

Abbreviations.—P = Paper; D = Discussion; I = Illustrated. Names of authors of papers, etc., are printed in *italics*.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XVIII. JANUARY, 1897. No. 1.

SEWER ASSESSMENTS.

BY F. HERBERT SNOW, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, December 16, 1896.*]

MR. PRESIDENT AND GENTLEMEN:

In preparing this paper I have drawn to quite an extent from a former report to the Sewerage Commissioners on a sewer tax for the city of Brockton. This place is a thriving inland city of 35,000 people, 20 miles out of Boston on the Old Colony division of the New York, New Haven and Hartford Railroad. The sewers are of the separate system, and the sewage is collected in a reservoir and pumped three miles to an area upon which it is treated by intermittent downward filtration.

FUNDAMENTAL OBJECT OF ASSESSMENT.

It is probable that the idea of assessments to help pay the cost of drainage originated in the early times when it was not considered practicable to effect drainage by public ownership. Under the law, the individual could lay and maintain a drain in a public way at his own expense, subject to the approval of the Selectmen; but if it became desirable to have abutting estates connected with the drain, such connection could not be had except by the payment, to the builder or owner, of such a sum of money, proportionate to the benefit derived, as the Selectmen should determine.

In time, the administration of the law became most unsatisfactory. Certain individuals would construct a sewer to benefit their particular estates without regard to the proper drainage of other

*Manuscript for advance sheets received November 14, 1896.—Secretary Ass'n of Eng. Socs.

property. The owners of this other property were obliged, later, in connecting with the sewer, to pay for drainage which was not adequate or complete. These methods of proceeding, and particularly private ownership of the drains intended for common use, fostered unprofitable disputes, jealousies and neighborhood quarrels.

As towns grew and private drains increased in number, the necessity of system and absolute public ownership became felt, and laws were enacted to bring about these results. But there does not appear to have been any opposition to the original idea of making owners of estates specially benefited pay a proportionate part of the cost, since all the new laws contained ample provisions for assessments.

Now, the design of a public system of sewers is to drain every house or building in the system. A small sewer is sufficient for the drainage of a few houses, but the sewer into which it and other pipes discharge must be larger, and the one into which they all discharge, larger still, so that small and large sewers are alike essential for the efficient drainage of single estates. So also may be the receiving tanks, the pumping station, force main, filter beds or other disposal works if they are provided.

But in some systems there are provisions made and items of expense which benefit the general public and not individuals. For instance, storm water, when allowed to accumulate on the surface of streets, becomes a public nuisance; hence the public should pay for its removal. In many instances, cities assume the whole expense of this kind of work.

We shall agree that public benefits should be paid by the public. Just how much public interest in the sewers should amount to in assessment should be settled by local conditions. Where the surface water drains and common sewers are combined in one system, then the general public benefit is much larger than in the separate system. The practice is becoming general to build separate conduits for the conveyance of sewage, putting off until future years the construction of complete systems of storm water drains. In case the drainage of water from streets is thrown out and placed among the problems of the future, the general public interest in a sewerage system is cleanliness of soil, purity of air, and purity of water. There may be actual benefits accruing to the whole city from the introduction of a sewerage system beside that of improved sanitation, such as its commercial value and the moral influence it has in maintaining and elevating the good name of the community. No one can tell how much these benefits may amount to, but they are not to be overlooked.

Taking everything into account, it is the custom to consider not less than one-fourth of the total benefit received as a public benefit, and legislation substantiates this view.

It is also fair to agree that private benefits should be paid by individuals, since the fundamental object of assessments is equality. Some cities assess the whole cost upon the property in the district sewered; others assess a part of the cost; and still others pay the total cost out of the tax levy, thereby admitting no special benefits.

Now, if the method of paying for a sewerage system is according to benefits received, outer districts should pay the smaller part and the district sewered the larger part of the cost. It is important to bear in mind constantly that it is the congested district only which demands efficient and complete removal of sewage; for beyond this district, unsanitary methods do not usually produce annoyance of enough magnitude to be called a public nuisance, the only remedy for which is adequate sewerage. Residents, whose principal interests are outside of the congested district, usually object to a large sewer tax. They say that if outlying districts which may ultimately come into the system, are compelled to contribute equally to the cost with those first benefited, it is manifestly unjust. On the other hand, there is injustice in making property in the congested district pay for the increased capacity of sewers which will be used only by the outer district.

Now, by provisions of statutory law, it is the duty of those in authority to use just and equitable methods in apportioning the cost of sewerage. This cannot be done unless the matter is thoroughly looked into and clearly understood.

Every investigator can find facts to satisfy himself that, up to the present time, sewer assessments generally have not been made proportionate to benefits received.

The latitude which the law of Massachusetts prescribes for the determination of ways of assessment, is sufficiently broad to allow of most unjust and inequitable methods.

THE FRONTAGE PLAN.

It is under authority of Chapter 50, Section 7, of the Public Statutes that the method of assessment can be made upon owners of estates within the territory to be sewered by a fixed uniform rate, based upon the estimated average cost of all sewers therein, according to the *frontage* of such estates on any street or way where a sewer is constructed.

The accompanying sketch will show plainly the injustice of assessing the cost of the sewers on the basis of frontage alone. The

instances cited are not in the least exaggerated. They are such cases as may be found in any city or town, and which will make themselves very prominent after a system of assessment by frontage is adopted.

We will assume, for the purpose of comparison, that the rate per front foot is one dollar.

In the case of the lot marked A, a man of means has built him a fine residence on a large corner lot, and if corner lots are not exempted on one street, he will pay $300 towards the cost of the sewers. If corner lots are exempted on one street, his assessment will be $150. Another man, owning lot C, which has the same frontage as A, builds upon it four two-tenement houses and connects them with the sewer. For the privilege of having the sewage of these eight families taken away he pays $150. A still more unjust possibility is represented in B; here the frontage is only eighty feet, and yet there are five houses entering the sewer, possibly double houses at that. The lots marked D and E are self-explanatory. On D is a large hotel, and consequently a large amount of sewage. Lot E is yet unoccupied. D would pay $50 and E $500, whereas the sewer for D would mean a considerable sum of money actually saved each year, and E's benefit would be entirely potential.

A perfectly equitable determination of the amount which should be assessed per front foot, where this system is adopted, requires a prophetic knowledge of the total cost of the sewers and the frontage on the streets in which they will be located. Such foresight being denied, the study should be to formulate, if possible, an assessment which will be fair at first, and also fair as the system is extended. Plans and estimates must of course be first prepared. If the sewer system be comprehensive, and the entire town be considered in determining the rate of assessment, the rate will be too small, for there are streets in which the sewers will not be built for many years, and perhaps never. On the other hand, if too little territory be included, the rate will be too large, as extensions will be made into territory not contemplated. It is thought that in determining the rate, that portion of the city or town in which it is assumed that sewers will be built within a reasonable number of years, should be alone considered.

THE AREA PLAN.

It is under authority of Chapter 50, Section 7, of the Public Statutes, that the method of assessment can be made upon owners of estates within the territory to be sewered, by a fixed uniform

rate, based upon the estimated average cost of all the sewers therein according to the area of such estates within a fixed depth from such street or way where a sewer is constructed.

To show the inequalities in the system of assessment by area attention is called to the following sketch:

The three lots marked A, B and C would have to pay equal sums, while A could put up three houses fronting on the street, B only two, and C one only. The land marked D, being nearly all back land, is of less value for building purposes, though it would have to pay much more than A and B combined. F, having only one frontage, would have to pay an equal sum with E, who has three frontages and an opportunity to build five houses on the

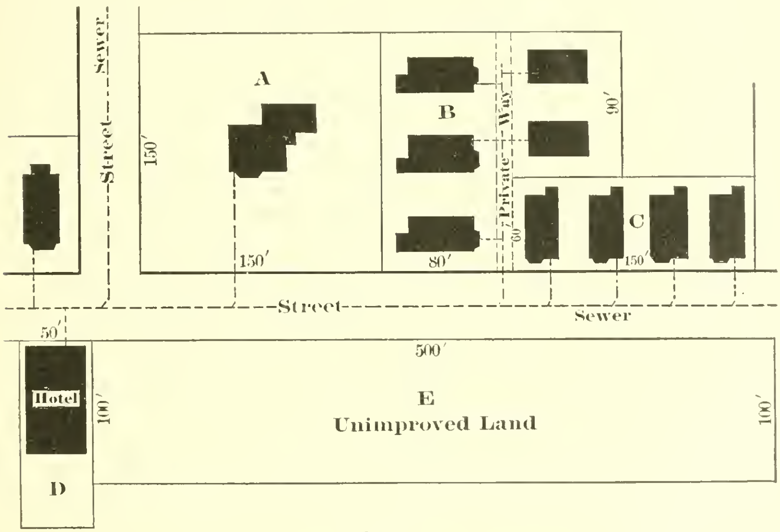


Fig. 1.

street. The lots marked G, H and I plainly derive more benefit from sewers than do lots of equal depth fronting on one street only.

FRONTAGE AND AREA COMBINED.

It is under authority of Chapter 50, Section 7, of the Public Statutes that the method of assessment can be made upon owners of estates within the territory to be sewered by a fixed uniform rate, based upon the estimated average cost of all sewers therein, according to both the frontage of such estates on any street or way where a sewer is constructed, and the area within a fixed depth from such street or way.

We have shown that the frontage system of assessment favors deep lots and works injustice to shallow ones; we have also shown

that the area system favors shallow lots and works injustice to deep lots. A combination of the two methods is adopted in some cities to obviate this discrimination.

If the assessments are divided between area and frontage de-

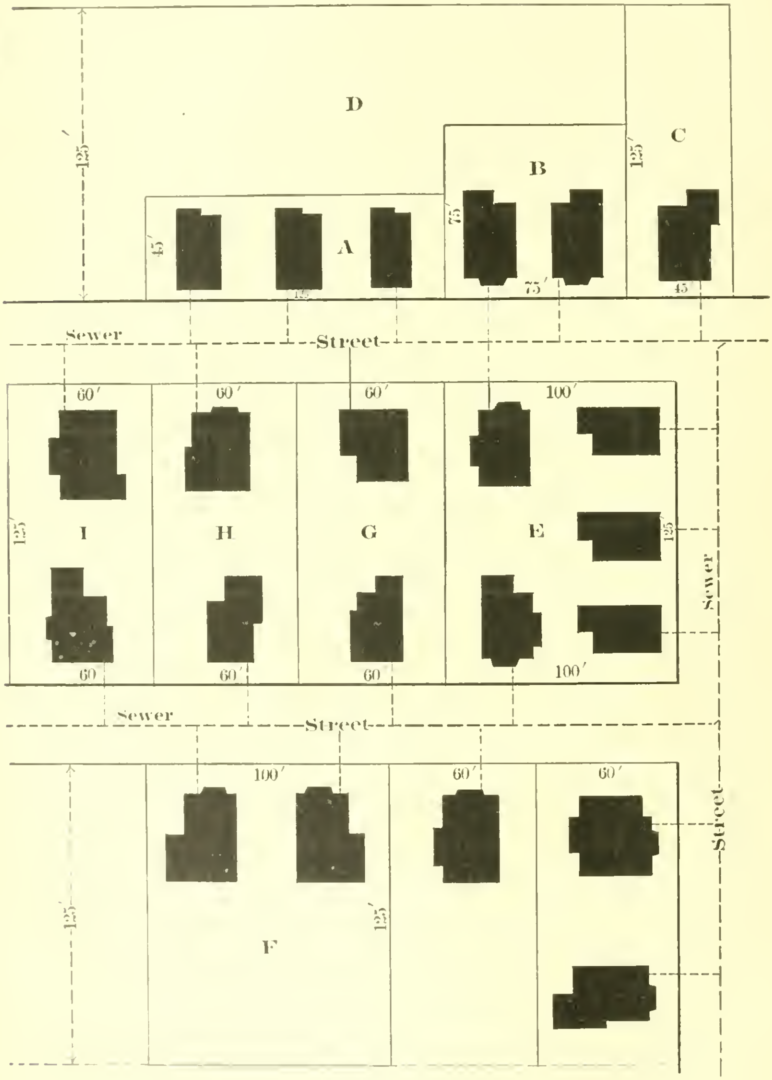


FIG. 2.

pending upon the relative value of each, absolute uniformity cannot be secured in devising a rule, since the ratio of value of area and frontage is seldom twice alike. Yet an average for the entire sys-

tem may be assumed and a rule formulated which will be more equitable than if the ratio were to be determined from time to time by the exercise of individual judgment.

Generally the greater the area which can be sewered, the greater the benefit, for with increase in area comes the ability to put up more buildings which may be sewered, while increase in frontage may afford no opportunity for the erection of suitable buildings.

The following sketch will illustrate this point:

There are two lots, A and B, of equal frontage and area; suppose A to be doubled in area without increasing its frontage, and B

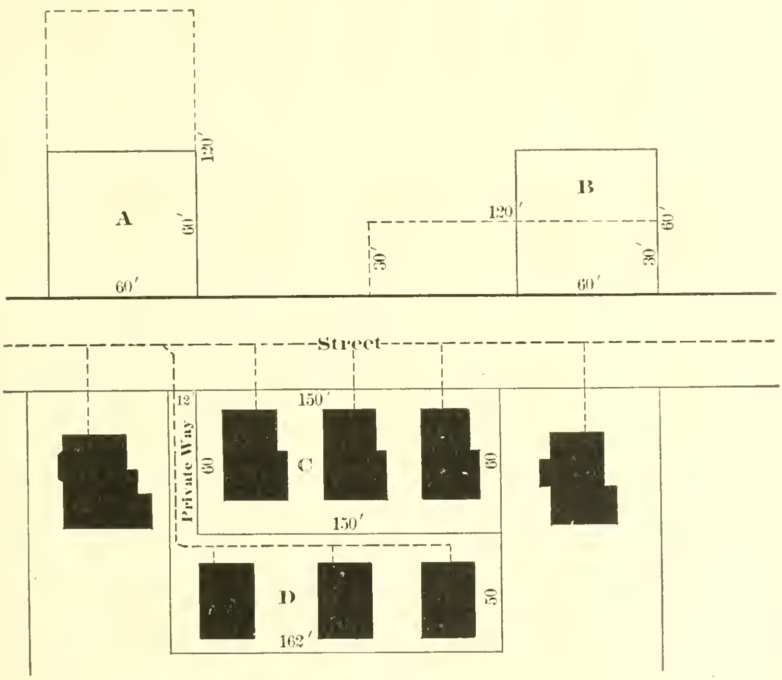


FIG. 3.

to have its frontage doubled without increasing the area. It is evident that A's ability to use the sewer is greater than B's, although B can enter more readily. In the case of C and D, the lots are of practically the same size, but D has practically no frontage and C has much. It is certain that D should pay more than half as much as C.

There can be no doubt but that the area is a more important factor than frontage, and so should pay a somewhat larger proportion of the cost.

A common division is to assess about six-tenths of the cost on the area and four-tenths on frontage. On this basis, assuming the amount per square foot of area to be one cent and the rate per foot of frontage to be fifty cents, and applying these figures to the property shown in the sketch, the following results would be reached: A and B would originally pay $30 for frontage and $36 for area, or a total of $66; with the lots changed as indicated in the sketch, A would pay a total of $102 and B would pay $96. C would pay $75 for frontage and $90 for area, making a total of $165, while D would pay $12 for frontage and $90 for area, or a total of $102.

THE ENTRANCE FEE PLAN.

It is under the authority of Chapter 50, Section 8, of the Public Statutes, that instead of paying an assessment, every person who uses main drains or common sewers in any manner shall pay for the permanent privilege to his estate such reasonable sum as the Mayor and Aldermen shall determine.

A reasonable sum for the permanent use of a sewer should be an equitable sum. How can this be determined? First, the whole number of buildings in the district can be counted and a uniform price fixed for each connection. It is not safe, however, to assume that over one-half of the buildings will be voluntarily conected, and there is no law that can force a connection where the estate is not a sanitary nuisance. This does not take into account future occupancy of vacant lots; or, second, a schedule of charges can be based upon the assumption that an entrance to the sewer on each side will sometime be made every sixty feet or so, and the cost can be divided among the total number of such entrances. By this latter method, a certain part of the cost belonging to abutters to pay, has to be raised by tax levy.

The great objection to this plan is that a uniform price for a single connection is not one of equality, since one connection may furnish facilities for draining one tenement, while another may ultimately drain several.

Some places have adopted the method of making a fixed charge for connecting, according to the kind of building to be connected. This method recognizes that some estates are benefited more than others; also that the cost to the individual should be levied in proportion to the benefit and not in proportion to the cost of the sewer. This is fair as far as it goes, but the benefit to land is not considered.

Legal authorities have concluded that if a benefit accrues to land by means of a sewer, the owner may be assessed whether he

chooses to avail himself of the sewer or not. Where an entrance fee only is charged, the benefit accruing to a vacant lot is not assessed. The owner sells the land at an advanced price and pockets all the gain. This is not fair.

THE VALUATION PLAN.

The early ordinances of Boston prescribed that every person connected with a sewer should be assessed according to the value of his estate, as shown upon the assessors' books, such a sum as should, in the opinion of the Aldermen, be just and reasonable.

In 1869 an ordinance was in force which prescribed a change in this respect, that the person or estate benefited should be assessed upon the *value* of the *land*, exclusive of the buildings or improvements thereon, and not upon the assessed valuation of the *entire estate*, as formerly.

For some wise reason, the Legislature modified the law and established the principle that assessments may be levied without reference to the *value* of the land.

Section 4, of Chapter 50, previously quoted, under authority of which the Mayor and Aldermen or Selectmen could assess the total cost of sewers upon the value of land, if they so determined, has been amended, so that now only three-fourths of the cost can be so assessed. To what extent should this privilege be exercised?

Now the authorities are bound to tax estates in proportion to the benefits conferred. The law does not confer upon them the right to tax an estate except for the benefit that is conferred. If there is no benefit there can be no tax. If there is a direct special benefit, the estate should pay for this particular benefit, and in direct proportion, as far as practicable.

Now the benefits of sewerage are not in ratio of valuation. For instance, A owns land which is worth $2 per square foot; B owns property which is worth ten cents per square foot. By putting in a sewer, B's land is enhanced in value ten cents per square foot, or practically 100 per cent., while A's land is enhanced the same amount—ten cents—or an advance of 5 per cent. For this 5 per cent. advance, A pays ten times more than B, though B obtains an advance of 100 per cent.

Again, a sewer may not be worth any more to a house on A's high-priced land than to one on B's low-priced land. In fact, where there are no sewers usually the cost of removing the contents of privy vaults is a uniform price per load, without respect to the building from which it is taken. Would there be any justice in the plan of obliging A because his land is worth $2 a foot, to

pay $2 per load, and B, whose land is worth ten cents a foot, to pay ten cents a load? Yet this is the principle of valuation.

Again, two properties may have an equal valuation and yet not derive equal benefits. One value might be in a water privilege, and another in a hotel. Often social tendencies render property more valuable on one street than on another, and affect rents. But who would care to say that relative desirability of lots for residential purposes indicated relative sewerage benefits? Is it not the use of the sewer which largely determines the benefit? The benefit to the user may be explained by the quantity of sewage he puts into the sewer, but valuation does not take this into account. If this method were attempted, with equal justice a person could be required to pay for water, or gas or car fares, or anything purchasable, according to the valuation of his estate.

Now while the cost of sewerage may be assessed according to the valuation of properties benefited, assessments which are neither just nor reasonable are at variance with the intentions of statutory law, and hence liable to be set aside. As equity and law go hand in hand, the priciple of sewer assessment based upon valuation does not seem well founded.

GENERAL TAXATION.

Before any assessment system can be devised, the question must be settled,—how much is the public to pay? Section 9, of Chapter 245, of the Acts of 1892, provides that every city or town shall pay a part of the cost of the sewerage system, which in no case shall be less than *one-quarter* nor more than *two-thirds*. The public share is levied upon personal property as well as real estate. While it is fair to tax personal property, it ought not to be taxed as much as real estate, since the latter is enhanced in value, while personal property is not. The general tax-rate cannot discriminate, therefore the larger the public share the greater the injustice to personal property.

Again, those who first enjoy the benefits of sewerage should pay more than those who will not be able to avail themselves of it for years. A valuable block situated in the center of the city should pay a larger sum than an extensive estate in the rural district where a sewer may not be built for fifty years. The reason the block should pay more is not on account of the number of square feet of land or its value, since the country estate may have a larger area and a higher valuation; nor on account of the cost of the building, since the mansion may be worth more than the business block; but it is on account of the respective needs of the estates for sewerage. This should be a strong argument against

apportioning a large amount upon the public, since by general taxation all property would pay the same percentage without regard to relative benefits.

Because sewerage enhances the value of land, owners should pay for this benefit. Another benefit is obtained by the use of the sewer, and as the greater the benefit, the greater the proportion to be paid, the users should pay the largest tax, the land owners the next, and personal property the least.

The writer inclines to the opinion that the minimum amount, equalling one-quarter of the cost, should be the public apportionment where the sewers are of the separate system.

THE RENTAL PLAN.

The healthfulness of a populous district demands a public supply of pure water and a proper and speedy disposal of the same after its use. The sewer is built for the water takers. The water taker's need of a sewer is directly proportionate to the quantity of water which will enter the sewer; therefore it seems just that, as he pays for the water delivered, he should pay for the sewerage removed.

It is under authority of Section 1 of Chapter 245, that the local authorities may determine that any debt contracted for sewer purposes may be paid from sums of money collected as annual rents. The same chapter also provides that only three-quarters of the total debt can be so raised; but in every community can be found those who adhere to the opinion that the *total* cost of sewerage should be paid by a tax to be levied annually as rental on those who use the sewers in proportion to their use. The Legislature could grant special authority to establish such a system, but from what follows it can be seen that its supporters would find it difficult to present for approval a definite plan.

Sewer rental based on the water consumption is ideal to the extent that the variable amount which the consumer pays rests in his hands. To be perfectly fair, however, the method should require that every building have its water service metered and the water not entering the sewer determined. If the use of meters would disturb the acceptable workings of the water department and require undue compulsion, the nearest plan to it is to charge a certain sum per 1,000 gallons for metered buildings, allowing a discount for water not reaching the sewer, and a charge for unmetered connections in rates of probable quantity of water used.

In working out this problem, before the sum to be charged per 1,000 gallons to give an income sufficient to pay all annual ex-

penses could be computed, it would be necessary to know what the annual expenses were to be, and how many 1,000 gallons (the assessable unit) there were to be; these involve several assumptions. Then as the yearly cost would naturally vary and the assessable units would increase in number, the rental would have to be annually changed.

Where the whole cost is to be raised by rental, it becomes necessary to assume that every building on the line of the sewer shall be connected, unless the cost is to be distributed among those who voluntarily use the sewer. If compulsory connections were legal, which they are not, the injustice of entailing an immediate expense of from $100 to $200 upon every estate, without respect to the financial ability of the owner to sustain this outlay, would result in the abandonment of the plan. On the other hand, the injustice of making the few who chose to connect pay the whole cost would result in disastrous consequences, as only a very few could afford the benefits of sewerage; thus the fundamental object of the sewerage system would not be secured and the whole scheme would be stigmatized as a monument to shortsightedness and incompetent government.

Again, there is no law which has as its intent the collection of a larger sum of money than is necessary to meet the sewer debt. If rental, designed to meet the whole cost, fell short of this, there would be a deficiency which would have to be drawn from some other source; but if it were in excess of this cost, strictly speaking, the whole assessment would be void. Now, it is very apparent that, with no knowledge of the actual number of persons who would seek the first opportunity of connecting their estates with the sewers, or of the number or the order of subsequent applications to enter, and with no knowledge of the actual cost of each year's expenditure for sewer construction, maintenance, etc., and with no certainty of the quantity of water which the buildings connected would turn into the sewer system—any one of these items being an important factor in the problem of apportioning the charges so as to collect enough money to defray all sewerage expenses, but not to exceed this amount,—it is almost if not quite impossible without additional legislation to devise a rental system so that the total cost can be raised in this way.

But it is practicable to devise a rental system so that a part of the cost can be raised in this way.

THE BROCKTON PLAN.

In the Brockton system, designed by the writer, one-half of the whole cost of the sewerage system, estimated at $1,300,000, and

the maintenance is being paid by equitable annual charges for the use of the sewers determined upon the basis of water service as follows: For unmetered water service eight dollars, and for metered water service thirty cents per thousand gallons of sewage delivered to the sewer, as shown by meter readings of the water department; provisions for discounts are made and such charges are collected quarterly; one-fourth part of the whole cost of the sewerage system is being paid by a fixed uniform rate of fifteen cents per linear foot of frontage—partially exempting corner lots—and three mills a square foot within the fixed depth of 125 feet; the remainder, which shall be a sum not less than one-fourth nor more than two-thirds of the annual sewerage expenses, including installments, interest on bonds and maintenance, sufficient to meet all deficiencies in the preceding year, the Sewerage Ordinance provides shall be appropriated annually by the City Council, to be raised by taxation.

As you perceive, this assessment system is based on a completed sewerage system. No scheme planned on these lines can be expected to hold good during the transitory condition of the early years. It is when the sewerage system is completed that the stated proportions will have been developed.

The amount received from rentals is not expected in the early years to meet the proportion of the cost allotted to rental. All deficiencies are to be made up from the general tax levy. The amount so raised will vary annually, but not to an extent beyond the scope of the scheme of assessment. The rental unit has been fixed at a rate that will not have to be changed for a long time. With a fixed rate per 1,000 gallons and a yearly increasing number of gallons, the total collected as rents will increase steadily, and the amount necessary to be drawn from general taxation decrease in like manner.

Also in the early years, elsewhere explained, when cost of sewers will be high, first assessments will not return their proportion of the total cost; but gradually, as the system is extended, the deficiencies will disappear, and in the latter years the total collection amount to one-fourth of the total cost.

As stated, all deficiencies will be met by general taxation, which forms a safety-valve to the scheme of assessment. The plan annually draws on this tax in greater proportion than one-fourth until the permanent condition of a completed system makes the final proportion possible. Thus the city advances the money to carry on the improvements, expecting to receive back one-third, and in the end not more than three-fourths of the cost.

It is fair that the city should, in the interest of sanitation, aid

the work by advancing in the early years more than its assumed proportion, since without it the work could not be done.

It should be understood that first assessment, which is to meet one-fourth of the total cost of the system, represents the benefit which actually accrues to land. It is the price which the abutter pays in one installment. The value added to land depends upon its area and frontage and the units of first assessment are based upon these factors. It has been concluded that six-tenths of the value is realized by its area, and four-tenths by its frontage, and this rate was used. In finding the amount which must be charged per square foot of area, six-tenths of one-quarter of the total cost of sewerage was divided by the total number of square feet of adjacent land within a certain distance of the street line. This distance, fairly taken as one-half the distance between parallel streets in the well-built-up district, was 125 feet.

The disposition of moneys collected as first assessments is an important part of the plan. The Brockton sewerage bonds are payable in annual installments; first assessments, therefore, could not be applied to meet yearly cost, as they accumulate faster than the installments and interest. A surplus is on hand which we should like to have had put into a sinking fund; this not being practicable, all first assessments have been credited to construction account and the yearly cost—being installments, interest and maintenance—is met by rental and general tax levy. In this way the amount of bonds which it would be necessary to float is reduced one-fourth, and the yearly cost, maintenance excepted, in like proportion.

As rentals and general tax are to meet the yearly costs, two-thirds of this must be raised by rentals, as this is the same as having rental meet one-half of the total cost. Yearly costs vary each year, but it is not feasible to have the rental rates changed correspondingly. The number of assessable units of rental increases as sewers are extended, but before many laterals are built, the yearly cost upon capital already invested in the disposal works must be met. This, with the cost of maintenance, amounted to almost $30,000, or about two-thirds of the yearly cost of the complete system. It is therefore apparent that if rental were scaled to meet two-thirds of the yearly cost in the early years, when the number of assessable units is small, the cost per unit would have been very high. Yearly cost increases to a certain point, at which the construction of laterals is practically completed. Beyond this point the yearly cost decreases by the interest on installments annually paid off. An average yearly cost, fairly representing the amount

which must be raised for a considerable number of years, was ascertained, and from it and the probable number of assessable units at the time when construction is practically completed, the rate per unit was calculated.

Such a method gives a rate which will hold good for many years, though naturally it will be reduced as the bonds are paid off, until finally the rental will only have to meet two-thirds of the cost of maintenance.

The yearly income from rental and the rates per unit were obtained in the following manner. The number of assessable units in the district which it is assumed will be sewered was estimated in ratio of present rate of consumption. This comprised the units for houses, shops and unmetered connections. (The latter having been found to be 30,000 gallons computed.) Then adding 1 gallon per year per capita as probable increase in water consumption and deducting 70 per cent. for shops and 5 per cent. for houses and unmetered connections, the assessable units in each year were found.

The cost per unit was then found by dividing the assumed stationary yearly expenditure by the number of assessable units, when construction will be practically completed.

BROCKTON RENTAL PLAN.

Sample Page, Book No. 1. Meter Readings.

Name.............................				Name..............................			
	...............................St.				...............................St.		
	189	189	189		189	189	189
July.				July.			
October.				October.			
January.				January.			
April.							

Sample Page, Book No. 2. Rental Ledger.

Application No............ Name.....................................Street.

Date.	Index.	Gallons.	Rate per 1000 Gallons.	Amount.	Discount.	Net Amount.	When Paid.	Remarks.

Sample Page, Book No. 3. Abatements.

BROCKTON SEWERAGE SYSTEM. Abatements.

Name.	Location.	Ledger Page.	Account.	Amount.	Abatement.	Date of Account.	Date of Abatement.	Remarks.

Sample Copy of Rental Bill.

SEWER RENTAL.

Page............

....

.... Street.

Rent ... .

Form 16.

SEWER RENTAL.

Page...... No............

....

.... Street.

To CITY OF BROCKTON, Dr.

For Sewer Rental for Quarter ending..., 189

Meter Reading. { ....

................Cubic Ft.

................Gallons.

At Thirty Cents per 1000 Gallons. ....

Received Payment,

....

City Treasurer.

Bills for Sewer Rental are collectible the same as taxes and bear interest after 30 days.

The Brockton plan is not perfect. No system can be. House connections have been most desultory, not, however, on account of the rental, which averages from $8.00 to $9.00 per year, but on account of the expense of the incidentals. Many of the houses have to be altered to provide for bath rooms and closets. Often these changes require a system of heating, and when the whole work is complete and the carpenter, steam fitter, plumber, etc., have been paid, the owner finds that an expense of from $300 to $500 has been incurred. This discourages others, and consequently connections come very slowly. All new houses erected on the line of the sewer are provided with modern sanitary arrangements, and such tenements rent readily. The landlords of the old buildings must make improvements or suffer loss. Meantime the rentals are small, but this should not be considered a fault of the system.

Up to the present, no different rates have been allowed manufacturers. This may be considered a fault. It is true that a city is not a mercantile establishment, buying and selling for profit; neither should it offer bargains at less than cost; but in so far as one city is in competition with another to secure new industries and to keep those already located, just so far is it permissible for a city to go into the wholesale business in establishing rates to manufacturers.

Another injustice is the minimum charge of $8. Many do not derive this much benefit; others take water by faucet rates and pay as high as $25 per annum for water, but as the connection is unmetered, the sewer rate is but $8. A change regarding the minimum rate will probably be recommended by the Sewerage Commissioners.

PARTICULAR SEWERS.

It is under authority of Section 4, of Chapter 245, that the authorities of any city or town may lay, make and maintain particular sewers from common sewers to the street line, and the owner of an estate benefited by such a particular sewer, shall pay towards the cost and for the permanent privilege of using it, such reasonable sum as the authorities may determine. Said sum may be fixed at the estimated average cost of all such particular sewers within the territory for which the said system of sewers has been adopted. The authorities may, if requested by the owner of an estate to do so, contruct a particular sewer from the street line to any house or building, and charge said owner the actual cost thereof, and may make rules and regulations for the construction and use of all particular sewers.

In many cases it is not practicable to build to the street line. The plan is not a good one, because the sewer system ends where the house plumbing begins. It is not sufficient that the Engineer have charge of the street sewer only. His authority should go to the inside of the cellar wall. For the owner, it is best that there should be no licensed drain layers. His particular sewer can be built better and cheaper by a well-organized gang under the Engineer; there are no profits to pay; the cost to him is the actual cost of labor and materials. In this way he is satisfied. There is no tax. He is not compelled to enter where he does not want to. He outlines what he wishes, and pays the actual cost, no more.

In Brockton, this work is done by the Sewer Department. It is not optional—as the law says it may be—with the owner. It is compulsory, because, in making application for connection with the sewer, the department dictates the terms of the agreement, as the Sewerage Ordinance provides it shall. This method is satisfactory to the people.

The Rules and Regulations of the Department are as follows:

RULES AND REGULATIONS RELATING TO PARTICULAR SEWERS.

1.—All particular sewers shall be of such size and material, and laid at such grade and depth, as the Sewerage Commissioners may determine.

2.—All particular sewers shall be laid, and all connections made with the common sewers shall be made by the Sewerage Commissioners or their duly authorized agents, and by no other person or persons.

3.—No person shall be allowed to make any further connection with any particular sewer connected with a public sewer than that intended in the original permit, without first making application and obtaining permission to do so from the Sewerage Commissioners.

4.—All applications for private sewers shall be made in writing to the Sewerage Commissioners, upon blank forms furnished by the Commissioners, by the owner or owners of the property to be sewered, or by their duly authorized attorneys.

5.—In making application for particular sewers, the sum of ten dollars ($10) must be deposited with the City Treasurer, by the applicant, and the application must be accompanied by the City Treasurer's certificate of the deposit of ten dollars ($10), which sum will be placed to the credit of the applicant and be used to liquidate the cost of the sewer applied for.

6.—No plumbing of any building shall be connected with a particular sewer until the cost of the said particular sewer shall have been paid. When said payment has been made, the Sewerage Commissioners will issue a permit authorizing the connection of the house plumbing with the particular sewer. The said permit must be in the possession of the person making the connection at the time the connection is made. But until said permit shall have been issued, no person shall cut into or in any way interfere with the said particular sewer.

7.—Bills for sewer rental will be payable quarterly, on the first day of February, May, August, and November, at the office of the City Treasurer. Where meters are in use, the first bill for sewer rental will be based upon the average quantity of water used during the quarter.

8.—Any arrearages for non payment of sewer rental or charges constitute a lien on the real estate, and may be sued for and collected by the City Treasurer in the name of the city.

9.—No person shall be entitled to have any portion of a payment refunded on account of non-use of the sewer, occasioned by vacancy of the

premises, unless said vacancy shall extend over a period of three months or more.

The enforcing of the rules and regulations is done in the following manner. Upon applying for a connection and a particular sewer, the owner files a certificate from the City Treasurer of the ten dollar ($10) deposit, and in return receives a receipt.

Sample Copy—Treasurer's Certificate.

	TREASURER'S OFFICE.
Date........................	Brockton, Mass.,..................189
Name........................	*This is to certify that*
Street........................	....
No. of House................	has deposited the sum of TEN DOLLARS with the City Treasurer as a guarantee that he will connect his property at No...........................Street, with the CITY SEWER.
Amt..........................	........................City Treasurer.

Sample Copy—Receipt.

Form 19.

CREDIT MEMORANDUM.

M..

In Account with CITY OF BROCKTON SEWER DEPT.

Sewer Connection No..........at..Street.

..........................18	Deposit, - - - - - - - - - - $10.00
	F. HERBERT SNOW,
	By................................

The application is an agreement to pay the cost of the sewer before the house plumbing is connected, that the sewer shall belong to the city, and that the city shall be exempted from all damages, etc.

Sample Copy—Application.

APPLICATION FOR A PRIVATE SEWER.

BROCKTON,................................189

TO THE SEWERAGE COMMISSIONERS OF THE CITY OF BROCKTON:

The undersigned, being owner of the estate, requests that a particular sewer be laid from the............at No.........Street, and that the same may be connected with the ....Street sewer, and that................may be allowed to use such sewer for the purpose of disposing of the sewage of said........................

And the undersigned agree to pay to the said Sewerage Commissioners, before connecting said..................with the said particular sewer, all of the cost of said sewer, including all labor and materials, or any other expense incurred necessary for the proper construction of said sewer.

And the undersigned further agree to strictly conform to the laws and ordinances relating to sewers, and to the rules and regulations that are now in force or may be adopted in relation thereto, and also to the plumbing laws and ordinances, so far as they relate thereto.

And the undersigned further agree that no claim for damages which may be occasioned to such estate, or any property thereon in any manner, by the construction, use, or existence of such particular sewer or connection, shall be made against the City of Brockton.

And the undersigned further agree that the said Sewerage Commissioners shall have access, at all reasonable hours, to the said premises to see that all laws, ordinances, and rules relating to the sewer are complied with.

Accompanying this application is the deposit of Ten Dollars ($10.00), required by the Rules and Regulations.

No........	Signature,....................................
	Address,....................................

The plumber then files at the City Engineer's office a plan outlining the proposed exit of the sewer from the premises, which must bear the approval of the Inspector of Plumbing.

Sample Copy—Plumber's Plan of Outlet.

OFFICE OF	OFFICE OF	
INSPECTOR OF PLUMBING.	INSPECTOR OF PLUMBING.	
City of Brockton.	City of Brockton.	
Plan outlining proposed exit of sewer from premises of	Plan outlining proposed exit of sewer from premises of	
....	....	(Sketch in here.)
No. .... St.	No. .... St.	
............................Plumber.	by........................ Plumber.	
Approved,......................189	Approved,......................189	
JAMES W. BROWN, Inspector of Plumbing.	.... Inspector of Plumbing.	
No...............................	No.............	

Upon receiving the plan and certificate, the foreman's requisition for the construction of the sewer is made out and forwarded. When completed, the foreman returns a report of labor and materials, and submits a sketch and remarks on the construction, etc.

Sample Copy—Foreman's Requisition.

SEWER DEPARTMENT.	SEWER DEPARTMENT.	
CITY OF BROCKTON,...........189	CITY OF BROCKTON,...........189	
Foreman's Requisition for a Private Sewer for	Foreman's Requisition for a Private Sewer to be built for	
....	....	
at No.........................Street.	at No.........................Street.	
............................Plumber.	............................Plumber.	
Per order Sewerage Commissioners,	Per order Sewerage Commissioners,	
Application	Application	(Sketch in here.)
F. HERBERT SNOW,	F. HERBERT SNOW,	
No........ Clerk.	No........ Clerk.	
Remarks.	Remarks.	
....	....	
....	....	
....	....	
....	....	
....	....	
....	....	

Sample Copy—Foreman's Report.

SEWER DEPT.

No..........

HOUSE CONNECTION. CITY OF BROCKTON.

For..

At......................................Street.

189 Materials.

Pipe,

Cement,

Other Materials,

Foreman.

On back side of leaf remarks and sketch are made.

The items are entered in a book kept for the purpose, and the sketch of the particular sewer and the premises is drawn in its proper place in a location book.

Sample Page, Book No. 4—Cost of Particular Sewers.

No ....

For...,

Commenced...................................... Finished...Street, Ward......................,

Size Main Sewer..........inches.	Size House Sewer.........inches.	Average Depth of Trench.....feet.
" " Sub Drain...... "	" " Sub Drain..... "	Total Length................. "
Depth Trench at Sewer.......feet.	Depth Trench at House.......feet.	Average cost per foot, $...........

............189	Total Hours.	Rate.	Amount.	Materials.	
Foreman,				Ft. in Vit. Pipe @	
Laborers,				Ft. in Vit. Pipe @	
Team,				Bbls. Portland Cement @	
Team,				Bbls. Rosendale Cement @	
				Labor,	
				Total,	
				Payments,	
				Deposit,	
				Balance,	

Sample Page, Book No. 5—Locations.

No. Street	No. Street.
Depth at Sewer, Grade,	Depth at Sewer, Grade,
Depth below sill, Connected,	Depth below sill. Connected,
☞Sketch.	☞Sketch.

The bill is at once rendered, and when paid a permit is given authorizing the connection of the house plumbing with the particular sewer.

Sample Copy—Bill for particular Sewer.

Connection No..........	Form 15.
Mr.......................	189
No. ....St.	Mr..Dr.
	To CITY OF BROCKTON SEWER DEPT.
Cost - - - $	To Cost of Connection No......
Deposit - - $10.00	At No..................Street.
Amount Due - $	Deposit - - - - $10 00
	....
	Amount Due, - - -
	Received Payment,
	....................................*City Treasurer.*

Sample Copy—Permit to enter Sewer.

BROCKTON SEWER DEPT.	CITY OF BROCKTON.
...............189	SEWER DEPARTMENT.
Duplicate permit to connect with private sewer, issued to	Brockton, Mass.,..................189
Mr.	Mr..........................owner of the........................
owner of the	at No.............................Street, having conformed in every particular to the prescribed rules and regulations of this department, is hereby authorized to connect or cause the plumbing of the said..........................to be connected with the particular sewer constructed for the purpose.
at No..................St.	
.............Plumber.	
Per order of the Sewerage Commissioners,	Per order of the Sewerage Commissioners,
F. HERBERT SNOW, Clerk.	F. HERBERT SNOW, Clerk.
No........	No..........

Over the question of connecting up there has been some dispute with the plumbers and at present the matter is pending in the court. The plumbers claim that Rule 6 interferes with their business, that it is not legal and that it is under the plumbing ordinance —which requires every joint to be tested to eight feet outside the cellar wall—that they must work. The plumbing ordinance, however, provides that the Sewerage Department shall build the particular sewer to the inside of the cellar wall. The Department could not carry on its work to advantage by stopping outside. The plumbers claim they cannot do their work to advantage by staying inside.

The outcome of the dispute has been that the plumbers have connected up when convenient, without waiting for the owner to pay and before a permit was issued. Consequently the Sewerage Department has had several hundred dollars out at one time which would otherwise have been paid. Of course, it is not right for the city to advance money to build a private sewer, and then wait several months for payment. Suit was therefore brought against the plumbers and the city now waits for the decision of the court.

The Sewerage Ordinance does not state, only by inference, who shall issue the permit to connect. Upon this point the plumbers pin their hope of success.

The ordinance relating to sewerage and sewerage assessments is as follows:

Be it ordained by the City Council of the City of Brockton, as follows:

Section 1.—The Sewerage Construction Commissioners shall have the direction and control, subject to orders of the Board of Aldermen, of all the common sewers of the city and of the construction, maintenance, repair and use of the same and may make such Rules and Regulations relating thereto as they shall judge expedient, subject to the approval of the Board of Aldermen. The City Engineer, under the direction of said Commissioners, shall have the general supervision and inspection of the construction and maintenance of all common sewers built or owned by the city, and of all connections of particular sewers built under the provisions of Section 4 of Chapter 245 of the Acts of 1892. He shall make and prepare all plans and needed specifications designed to govern the work of construction; when the sewers are to be constructed, he shall cause accurate plans thereof to be made, representing the location, depth and material with a section plan of each sewer, indicating the size, shape, thickness and construction, and he shall cause to be shown upon said plan all existing connections of said sewers and all public connections as they are made.

Sec. 2.—One half of the whole cost of the Sewerage System,

estimated at $1,300,000, including the cost of laying, making and maintaining its common sewers, shall be paid by equitable annual charges or rents for the use of such sewers, by the persons who enter the same, and one-fourth part of such whole cost shall be paid from assessments upon estates receiving benefit according to the frontage of such estates on any street or way when a sewer shall be constructed and according to the area of such estates within a fixed depth as hereinafter prescribed, and the remainder shall be paid by the city and raised by general taxation; all of said assessments, charges and rents to be made, certified and collected as hereinafter prescribed.

SEC. 3.—An assessment shall be made upon the owners of abutting estates, by a fixed uniform rate based upon the estimated cost of the entire system, of fifteen cents ($0.15) a linear foot of frontage of such estates on any street or way where a sewer is constructed, and of three mills (0.003) a square foot, according to the area of such estates within a fixed depth of 125 feet from such street or way; but no area shall be assessed more than once.

No assessment in respect to any such estate which, by reason of its grade or level, or for any other cause, cannot be drained into such sewer shall be made, certified, or notified until such incapacity is removed. When such estates abut upon more than one such street or way, such assessment shall be made upon the whole of the longest frontage, and sixty feet of the frontage upon each other such street or way shall be exempted from such assessment, but all in excess of said sixty feet exempted shall be subject to assessment.

In making such assessment the frontage shall be assessed to the nearest foot and the areas shall be determined from the plans on file at the Assessor's Office.

The Sewerage Construction Commissioners shall direct the City Engineer to prepare and submit plans to the Board of Aldermen, showing the estates to be assessed, giving the owner's names, frontages and areas, together with a schedule showing the assessments on the estates abutting and benefited. The amount assessed and certified by the Mayor on behalf of said Board shall be entered upon the plans prepared for assessment, and shall, for two years after they are laid, constitute a lien on the real estate assessed, and shall, together with all incidental costs and expenses, be levied by sale of such real estate, if the assessment is not paid within three months after a written demand for payment, made upon the person assessed, or upon the person occupying the estate; such sale to be conducted in like manner as sales for the payment of taxes.

Owners of estates or parts of estates not liable to assessment as aforesaid, or not in fact assessed, shall pay for special benefits to such estates such reasonable sums as the Mayor and Aldermen shall determine.

The Collector of Taxes upon receipt of the schedule of assessment certified by the Mayor, shall forthwith render notice of assessment and amounts of the same to the parties assessed therein, and the said amount shall be due and payable thirty days from the

date of such notice, after which time interest will be charged thereon at the rate of six per cent. per annum.

Sec. 4.—Every person or owner of an estate, who enters his particular sewer into a common sewer, shall pay for the use of such sewer an annual rental determined upon the basis of water service, as follows: for unmetered water service, eight dollars; for metered water service, thirty cents per 1,000 gallons of sewerage delivered to the sewer, the quantity so delivered to be determined by the meter readings taken by the Water Commissioners, but the annual charge shall in no case be less than eight dollars, it being provided, however, that in cases where said Commissioners shall deem the same to be equitable, a discount may be made, such discount to be determined by said Commissioners and approved by the Mayor and Aldermen; and it being further provided that any such person or owner may place, at his own expense, a water-meter which shall be approved by the Commissioners, to measure the amount of water which does not enter the sewer.

Such charges shall be collected quarterly and shall constitute a lien upon the real estate using the sewer, to be collected in the same manner as taxes upon real estate, or in an action of contract in the name of the City of Brockton.

Sec. 5.—The City Council shall appropriate annually, to be raised by taxation, a sum not less than one-fourth or more than two-thirds of the annual sewerage expenses, including installments, interest on bonds and maintenance, sufficient to meet all deficiences in the preceding year.

Sec. 6.—Whenever any street is opened for the laying of pipes for water, gas or other purposes, or for the prosecution of any works of connection, such laying of pipes and the work connected therewith, or such work of construction, shall be so executed as not to obstruct in any way the course, capacity or construction of a common sewer; and whenever pipes for any purpose or any work of construction are found to exist at such depth, or in such location as to interfere with any existing sewer, or with the building of any common sewer of the required size, and at the proper depth and grades, the department, corporation or person maintaining the same; shall, upon notice thereof, at once remove, change or alter said pipe or pipes, or other works, in such manner as the Sewerage Construction Commissioners may direct. If such department, corporation or person, neglects to comply immediately with the terms of such notification, the Sewerage Construction Commissioners may make such removal, change or alteration, and the cost thereof shall be paid by such department, corporation or person.

Sec. 7.—All applications for the construction of particular sewers and their entrances into common sewers, and for permits to enter the same shall be in such form as the Sewerage Construction Commissioners shall prescribe, and be filed with the City Engineer. All such particular sewers, and their entrances into common sewers, shall be constructed, maintained and kept in proper

repair by the Sewerage Construction Commissioners, and shall be the property of the city, and the cost thereof shall be paid by the owners of the estates connecting, before the same are used or house connections made therewith; the cost of all repairs made thereon shall be paid by the owners of estates connecting.

SEC. 8.—No person shall enter or attempt to enter a private drain or sewer into a common sewer or its connections, or into the underdrain constructed in connection therewith, except he is duly licensed thereto, and no person shall cut into, interfere with, or obstruct a common sewer.

SEC. 9.—No person shall throw or discharge into a public sewer or any of its connections, any steam or other matter or thing which may tend to, or cause, an obstruction thereof, or a deposit therein, or any injury thereto.

SEC. 10.—Any person violating any of the provisions of this ordinance shall be punished by a fine not exceeding twenty dollars for each offense.

DISCUSSION.

MR. ALLEN HAZEN.—I am much interested in the method mentioned by Mr. Snow of collecting money for the support of the sewerage system, particularly that part of it which was reckoned at a definite rate per thousand gallons on the water used, as recorded by the meters of the water department. In cases where it is necessary to collect, pump, and treat sewage there is entailed upon the city a very considerable expense, which is substantially proportional to the amount of sewage contributed, and consequently nearly proportional to the quantities of water taken by the citizens and establishments; and it seems to me that in such cases it would be eminently fair and proper to charge for water used a certain sum per thousand gallons in addition to the sum necessary to provide for the support of the water department, such additional sum being as nearly as possible that which would provide for the collection, pumping, and purification of the sewage. It would be simpler, and perhaps in other respects better, simply to add this rate to the ordinary water rates, so that the money would be collected by the water department, and could then, if desired, be turned over to the sewer department as a lump sum.

The plan of an annual tax upon dwellings in payment for the removal of sewage was adopted by the city of Paris by the law of July 10, 1894,* which provides that a charge of $2 annually shall be made on dwellings renting for less than $100 per annum; $6 on

*Annales des Ponts et Chaussées; 7th series. Vol. IX, Page 318.

houses renting for more than $100 but less than $300 per annum; $12 on houses renting for $300 to $600 per annum; $16 for houses renting for $600 to $1,200 per annum; $20 for houses renting for $1,200 to $2,000 per annum, and so on up to $300 for houses renting for more than $20,000 per annum. It is understood that these charges are less than the cost to the householders of disposing of their sewage in any other way.

Mr. George A. Kimball.—The paper which we have just heard is a very interesting one, not only on account of the facts which it contains, but also of the very able manner in which the different methods of sewer assessments are discussed.

The rental portion of the system as adopted in Brockton may act in some degree in preventing owners of property from making a free use of the sewers in order to avoid the annual expense. Every inducement should be held out for the immediate removal of all filth, and one way to induce people to keep clean is for the authorities to remove all waste at the least expense to the householder.

The arrangement of a proper system of sewer assessments is not an easy matter, and it has been the cause of considerable agitation and difference of opinion in many cities where sewers have been constructed. Some towns in Massachusetts, where sewers have been constructed under a special act of the Legislature, have omitted entirely to make any assessments on the property benefited, but have allowed the town to assume the whole expense. That the property benefited should pay a large part of the expense in sewer construction is well established, and it needs no argument from me. The question of what proportion it should bear is an interesting one, and one on which there has been considerable difference of opinion. The public statutes provide that the town shall not pay more than two-thirds nor less than one-quarter, but in cases where special acts have been passed this proportion has been ignored.

It frequently happens that the laying of a sewer assessment creates such a strong feeling in the city or town where the sewer is built that influence enough is brought to bear upon the City Council, or upon the voters in town meeting, to change the amount of the assessment from time to time. It is a very common thing for our people to resist any taxation, and if, by hard work and influence, they can induce the members of the City Council to change the assessment or modify it in some way which may result in their benefit, they are willing to use every effort to accomplish their end.

The ordinary taxes which we pay are determined by the acts of the Legislature, which make it incumbent on each town to tax its owners of property, and the city or town authorities must enforce it. It seems to me that this same system should be employed in regard to the sewer assessments. As it is to-day, a man in town meeting may carry a vote which would entirely change the form of the sewer assessment, or a few men composing a City Council may sometimes change an ordinance in order that the existing system of assessments may be changed. But if the amount of assessment is fixed by statute, then each would share alike.

The town of Arlington, Mass., is now building a sewer system under a special act of the Legislature passed in 1896, which requires that every estate benefited by the construction of the sewer in the street on which it abuts shall pay to the town 28 cents per running foot frontage on the street or way on which the sewer is constructed, and 0.52 cent per square foot area within a depth of 100 feet from the line of such street. It also provides that assessments may be laid upon any street as soon as the sewer is ready for use.

The advantages of this system are its stability, which requires the act of Legislature in order to change it, and also the fact that the assessments may be collected immediately after the sewer is built, without waiting for the completion of the whole system and the determination of its cost.

These assessments go to the credit of the sewer appropriation, and are used in extending the sewer system. In Arlington the system is estimated to cost $283,000, but the amount to be borrowed will not exceed $100,000, the receipts and assessments being sufficient to make up the difference.

Mr. George Bowers.—I have been very much interested in Mr. Snow's paper, and I agree with him most thoroughly when he says, "Every investigator can find facts to satisfy himself that up to the present time sewer assessments generally have not been proportionate to the benefits received." But if he carries out his rental plan as just described, there will be one marked exception to the general rule.

The varying conditions of each city or town require a different solution of the sewer assessment problem. If the sewage is to be treated and the effluent made clear and inoffensive, the cost of maintenance is a very different thing from that of a system of sewers emptying into tidewater, where no treatment is required. The frontage plan, so far as I have investigated, has the most advocates, and, in my judgment, is the most unfair. I consider the

area plan more equitable, but it has its faults, as has just been shown. The Lowell method, which I do not recommend, is to assess one-half the cost, or less, of all sewers, upon the abutters on the street in which the sewer is laid, making the assessment vary in every street; sewers laid in streets where there is a large amount of ledge excavated costing very much more than sewers built in streets where there is no ledge. This method gives a great deal of dissatisfaction when people living in different streets compare their sewer bills, or where the same person has bills from different streets. Abutters will pay readily a sewer assessment amounting to not over 1 cent per square foot, which would be $1 per running foot on lots 100 feet deep, but when the assessment is more than that they try to get it reduced.

I believe that where no treatment of the sewage is required the assessment should be made by a combined system, using the frontage and area, taxing $\frac{3}{4}$ cent per square foot for lots to a depth of 100 feet, with 25 cents per front foot, and assessing corner lots but once for area, but for the full amount of frontage on the second street. It is an advantage to a corner lot to have a sewer in both streets, and it should be assessed for it. By this method the city would pay one-half the cost of the sewer, and the abutters the other half.

Some will say that the city would not get back a fair proportion of the cost, and that the people not entering the sewers would have to pay too much. This objection I would answer by saying that by the system in use with us (that is, the combination of surface drainage and sewage) the general tax-payers should pay their part for the drainage of the streets and for taking care of the surface water. Looking at the problem from this standpoint and from that of considerable experience in the making up of sewer assessments, and knowing of no rule that has ever been made which was satisfactory in all places, I believe this would be the best method to be adopted by a city situated as we are.

Mr. F. P. Stearns.—When I occupied the position of Engineer of the State Board of Health, which has a general supervision of the water supply and sewerage of the State, I could not help being struck by the fact that nearly every town of any considerable size had a system of public water supply, which was available to a very large proportion of the citizens, while sewerage systems were confined almost wholly to the cities, and in them the sewerage systems were by no means as extensive as the systems of water supply. It seemed to me that the prevailing methods of paying for the cost of the works were, to a very large

extent, responsible for the difference in the progress of the two systems.

The general policy in regard to water works has been, and is, to pay for the system by a loan, and to collect a yearly rental from those who actually use the water. The annual charge to the water-takers is made such that the amount remaining to be paid out of the tax levy for the maintenance, interest, and sinking fund is no more than a proper payment, on the basis of valuation, for the value of the water system to the community for fire protection.

The result of the almost universal adoption of this policy has been that towns feel warranted in issuing large loans for water works purposes, because they are well assured, in advance, that it will not be a burden to the people, or cause a serious increase in the tax rate. This policy has been so satisfactory that it has been fully recognized in legislation, as, in determining the debt limit of a town the water debt is excluded. Moreover, the public statutes provide that a water loan may run for a longer term than any other loan.

Sewer systems, on the other hand, have generally been paid for by taxation, very heavy initial payments upon lands bordering upon the streets where sewers are laid, and loans of comparatively short terms. Little or no provision has been made for any revenue from the use of the sewers, and the maintenance of the system, together with a considerable part of its first cost, have been borne by taxation. The dread of higher taxes and of the large initial payments has very much retarded the extension of sewers, even in places where the public would be ready and willing to pay a rental sufficient not only to pay, ultimately, the first cost of the sewers, but also to make them practically self-sustaining.

If for the past twenty years water works had been built upon the same basis as the sewerage systems, there would be, in my opinion, not half as many towns at the present time provided with a public water supply, or, if so provided, it would be through the agency of private companies rather than by municipalities.

From a sanitary standpoint, and for the general welfare of the cities and towns of the State, particularly those which have not already partially-completed sewerage systems, I think it extremely desirable that a rental system should be adopted, to pay a part or the whole of the cost of the system.

Let us consider, in a more general way, the question as to what is the best public policy in the matter of paying for sewers. There seem to be three general principles upon which assessments have been made: First, in accordance with the cost of the sewer

in the street or district; second, on the basis of the benefit to the owners of lands or buildings affected by the sewers; and, third, upon the basis of ability to pay. The assessment according to the cost of the sewer in the street has come down to us from former times, and I think it will need no argument, at the present day, to show that a person should not pay a larger sum for connecting with a large sewer instead of a small one any more than he should pay a larger water rate if his water comes from a 12-inch pipe in the street instead of a 6-inch pipe.

With regard to the question as to whether a person shall pay in accordance with the benefits received, or in accordance with his ability to pay, it is well to consider methods of payment for other public and semi-public institutions and works. If we take the case of education in the public schools, the public policy universally adopted in this country is that a man shall pay in accordance with his ability to pay, and not in accordance with the benefits received. A man who has no children and is assessed for $100,000 may be required to pay $300 a year, while the poor man who has no property and six children to go to the public schools pays a poll tax of $2.00, notwithstanding that the cost of educating his children per year may be $25 each, or $150. If we take the public or semi-public works which are sometimes owned by the municipality and sometimes by private corporations, such as the water works, the subway, the lighting plants, and the street cars, the general policy is that the payment shall be on the basis of benefits conferred, and that the works shall be made self-supporting, so that they will not add to the general tax levy. By this I mean, not that the tax levy pays nothing, but that it pays only incidentally, as in the case of water furnished for fire protection, lights used in schoolhouses, public buildings, etc.

I think it is a safe rule to adopt that where any public works might be carried on by a private company, and the municipality concludes, instead, to adopt the policy of municipal ownership, such public works ought to be self-sustaining, and not a burden upon the community to a greater extent than they would be with private ownership. On the other hand, things which are essential to a community, and yet so costly that they cannot be paid for by the poorer people—like public education—should be borne by general taxation, on the basis of ability to pay. The adoption of this rule would lead to a growth in the number and kinds of works under municipal ownership, provided the municipalities continue to show that they are capable of carrying on public works in an economical and satisfactory manner. The showing thus far in the

case of water supplies generally, in the case of the subway now building, and in many other cases, has been very satisfactory.

It is somewhat difficult to decide to which class sewerage systems belong. These systems have, in a few cases, been put in by private companies, but I believe it is a wise public policy that has determined that they are too important to the health of the community to be built in this way, and that they should be built under municipal ownership.

There may be cases where the people cannot afford to pay for a system of sewers in proportion to the benefits received, and yet a system of sewers may be essential to the health of the community. In such cases it may be wise that a large part of the cost should be paid by those who have the ability to pay, or, in other words, by taxation; but in the great majority of cases I believe that the bulk of the cost should be paid by the people benefited, and that this can best be done by an annual rental sufficiently large to furnish a revenue which will ultimately pay for a very large proportion of the cost of the works and their maintenance.

Payment acording to the benefits received can be made wholly by rental, or partly by a rental and partly by the payment of a portion of the cost of the sewer by the owners of the land abutting on the streets through which the sewer is laid, and in other ways. Where the people can pay a large initial assessment without difficulty, it may be well to diminish the amount of the sewer loan by collecting such an assessment, but I think the cases are rare where this method is not burdensome to some of the people, and does not cause objections to be made to the construction of sewers, objections which retard their adoption and extension in the cities and towns. I therefore question whether it is not the wiser policy, as in the case of laying the water pipes, to ignore the benefit to lands not built upon, and to raise the whole amount to be raised otherwise than by taxation, by charging an annual rental to be paid only by those who have buildings which can be connected with the sewer. I would make the rental begin whenever it became possible for a building to connect with the sewer, as this would have a tendency to promote the making of connections, which is so desirable to the health of a community.

The statements made in the written and verbal discussions of this paper this evening by those who are associated with sewerage systems where a large initial assessment is required tend to confirm me in the view that it is unwise to make them. There has been a general consensus of opinion that where a large sum is assessed in the beginning the people try, and often successfully, to

get the amount reduced. In some cases, cities or towns have changed the method and reduced the amount of assessments, and in others the Legislature has been appealed to for changes, and with success. The result has been that the amount collected by assessments has been disappointingly small, and the amount put into the tax levy so large as to cause discontent and a retardation of the work.

Reference has been made, in the case of the town of Arlington, to the advantage of having the amount of the assessment determined by legislative act, so that those assessed cannot go into a town meeting and have the assessment reduced. I think no one can doubt that this is good policy where an unpopular and burdensome assessment has to be collected; but is it not rather an argument for the adoption of the more popular and less burdensome method of raising the required money by an annual charge? No one asks a Legislature to determine the water rates of a town, as it is generally agreed that it is better that the principle of local option should apply in this case. Would there be any greater reason for asking a Legislature to determine the sewer rates, if the principle of an annual charge were adopted?

I was very much pleased with Mr. Snow's report upon sewer assessments in Brockton, and was very glad that it was put into effect, furnishing, as it did, in this State a definite example of a system in which the yearly rental is an important factor, and I am not at all sure that the plan which he devised is not, in a majority of cases, the very best one which can be adopted. I do believe, however, that each place is likely to furnish, to some extent, an independent problem, and I should give a good deal of consideration to the question as to whether a larger sum of money cannot ultimately be raised, with less friction, by a slight increase in the rental and the omission of the initial payment.

Mr. Freeman C. Coffin.—I believe that it would be desirable in many cases to collect the cost of a sewerage system by some method of annual payments, thus making its financial management similar to that of a system of water works. In the latter, a certain portion of the annual cost of maintenance, including interest on the bonds and the amount provided for a sinking fund, is quite generally raised by taxation, and is considered a just payment made by property holders for the fire protection afforded by the water works. The proportion of this to the total cost of maintenance varies in different towns from nothing to 60 per cent.

There arise from a sewerage system general benefits which inure to the citizens and property holders, and which are distinct

from the benefits conferred by the actual use of the sewers. If the total annual cost of maintenance, including interest and a sufficient provision for a sinking fund to extinguish the sewer debt in a certain term of years, could be treated in a manner similar to the expense of a water supply system, the city paying its proper proportion from the general tax levy of each year, and the abutters and users the remainder, the problem of meeting the cost of sewers would be much easier. With such a system, something similar to the present methods of assessing abutters might be adopted, viz: Upon area and frontage. A third factor should be added which would represent the actual use or entering of the sewer. This factor should not apply to vacant lots. It is suggested that the water consumption be the third factor. Perhaps this would be the best basis where the water works are owned by the municipality. It might not be practical when they are owned by a private corporation to whose books the officials of the town have no right of access. The relation of the consumption of water to the amount of sewage is not so close as is sometimes assumed, and the proportion would vary greatly in different towns. There is much water that does not go into the sewers, as, for instance, that used on lawns, in boilers, for some kinds of manufacturing, and by railroads. So that, with this for a basis, some discrimination might be necessary. It is possible that the assessed valuation of the buildings, exclusive of land, would be practicable as the third factor, or that representing the use of the sewers.

It is suggested that the sewers be put under the charge of the water board, and also that the cost of the sewers be charged to the water takers. There might be advantages in having both departments under the same control, especially in small towns. I do not believe, however, that any part of the sewer expenses should be charged to water takers as such. The two accounts should be kept entirely separate, and separate bills or separate items should be rendered for each. The need of a sewerage system is not caused by the existence of the water supply. On the contrary, a modern separate system of sewers is made possible only by the existence of the water supply, and is indebted to it for a vehicle of transportation.

It would not be just nor politic to burden the water works with the expense of a sewer system. It would not advance the cause of sewer construction, but would create opposition. Even if the consumption of water is made the basis of a portion of the sewer rates, let the charge be a separate one for sewer service, not for water.

Mr. Louis E. Hawes.—I have been greatly impressed by the wide variation in the methods of assessing the cost of sewers. In compiling information on the subject I found that the methods range from the one in use in a western city, wherein there were reported to be 200 miles of sewers the entire cost of which had been paid by the abutters; to the methods adopted in several places in Massachusetts by authority of recent legislation, which approaches more closely to an equitable ratio of apportionment.

I fully concur in the opinion that the large first cost to the individual by the methods in vogue is and has been acting as a serious impediment to the extension of sewerage facilities in towns and cities, and firmly believe that if some method can be devised which will reduce the large first cost to the individual, it will have a wonderful effect in assisting the introduction of systems of sewerage into towns.

I would like to ask Mr. Snow whether, since sewers were constructed and connections made in Brockton, he has calculated the average assessment to the individual by the method adopted there.

Mr. F. Herbert Snow.—The average assessment for the cost of the system amounts to about 50 cents per linear foot, or, for resident estates, $30.

The rental averages from $8.00 to $9.00. I have yet to hear the complaint that this is an exorbitant charge. The fact is, it effects an actual saving, as the cost of removing the contents of the old cesspools and privy vaults was three or four times greater per unit. All the estates where tight cesspools were used, accepted the first opportunity to connect with the sewer. If the Board of Health should decree that every old, loose, leaking, and treacherous cesspool should be made tight and properly kept, such a demand for a sewer in every street would result as to dispel the notion that an $8.00 rental operates to make people opposed to sewerage.

This should be a satisfactory answer, in Brockton's case, to Mr. Kimball, who fears that rental might keep people from connecting. I agree with him that undoubtedly, if a sewerage system did not cost anything to them, many more estates would connect; but sewerage systems are expensive and the question is, "How can this inevitable expense be most equitably apportioned?" Why should not the estates benefited pay this cost? The time is coming when sewerage debts will be paid as water debts, and the poorer people will wonder why they ever submitted to be taxed under the old régime.

A strange fact is that the water bills generally have not in-

creased in houses connected with the sewer. The water consumption has slightly increased, but not enough to affect the water bills.

It is hardly fair to include the cost of particular sewers as a part of the first cost mentioned by Mr. Hawes, as it is a private matter, as also is the cost of plumbing and the changes inside the building. The average particular sewer from the street sewer to the house costs $26.00. The cost of the incidental expenses depends upon the kind of building and its surroundings. If the privy were in the back yard, the house plumbed only for sinks and without a bathroom and heating system, the cost usually means an addition to the house or remodelling inside for the water-closet and bathroom, some method of heating and modern plumbing for the entire house as per ordinance, which, as I said before, all told amounts to from $300 to $500. This first cost is the troublesome one in the City of Brockton.

I wish to anticipate exceptions to my statement that there is no law that can force a connection when an estate is not a sanitary nuisance. I am well aware af the Act of 1890, which provides that every building shall, when required by the Board of Health, be connected with the public sewer. This is one of the rules of our Board of Health, but the Board do not care to proceed under it to order a general connecting up over the whole city or on any particular street. The City Solicitor says the law is faulty and the Board prefers to use the regulation in individual cases with success, rather than to be defeated and shorn of its power by the concerted opposition of the community.

The law cited does not enlarge the duties of the Board of Health. To ascertain what they are prior statutes must be consulted, and one finds that the Board exists for distinctive purposes. It is only when the individual uses his property so as to threaten the health of his neighbor that this Board can have jurisdiction. It can then order a nuisance abated and the owner may have a choice of ways. But now the law of 1890 says: If required by the Board of Health, the building shall be connected with the sewer. That is, all the law does is to prescribe a compulsory remedy to be left in the hands of the health authorities. This interpretation of the law seems to be just and plain.

I have in my hand a copy of the Journal of the Massachusetts Association of Boards of Health.

In the spring of 1895 the Association visited Brockton and inspected the sewerage system, and in discussing sanitary matters this question of connection was brought up. This Journal contains an account of what was said.

Here is one officer who says, "That while we can compel connection with the sewer, we cannot, when there is an old privy and it is not a nuisance, compel the privy to be connected."

Dr. Durgin, of Boston, says: "You may make a party connect and he will connect something with the sewer, and leave his old vault or cesspool just as bad as before. The law should be amended so that we may get rid of those old vaults and cesspools."

Another officer says: "We have felt the same defect in the law. We have only been able directly to abolish privy vaults and cesspools in those cases where they were nuisances. Additional legislation will be very desirable to compel a thorough change in the premises at the time the connection is made."

Any member caring to read the full discussion can find it in the June number of the JOURNAL for 1895.

SEWER ASSESSMENTS IN BOSTON.

By Charles R. Cutter, Department Superintendent of Sewers.

It has been suggested to me by your Secretary that, as Superintendent of the Sewer Division of the city of Boston, I was in a position to give valuable criticism on the "Brockton Plan" of assessing a system of sewerage, as devised by the engineer of that city, Mr. F. Herbert Snow, and also to say why a "rental system" would not be applicable to the city of Boston. In view of the limited time in which I have had to consider such a very complicated matter, my criticism, if any, would be superficial and not worthy the importance of the subject. I can only say that I should consider Engineer Snow's plan a most ingenious and practicable method for equitably assessing upon the inhabitants of the city of Brockton the cost of its sewerage system, in proportion as they individually derived actual benefit therefrom, and a scheme valuable for guidance of the members of this society in building sewerage plants of similar size in cities and towns under similar financial circumstances.

Mr. Snow seems to have anticipated all reasonable criticism of his method, but I should suggest that the compulsory connection of all estates abutting on the sewers was a highly important desideratum.

Since the incorporation of the city of Boston in 1822, which is also the date of the public ownership of any structures that might be called sewers, the city has been struggling to assess as

a special tax upon those inhabitants directly benefited a proportion of the cost of the sewers built. From the mass of laws and ordinances promulgated to that end, there can be separated the following six general laws for the assessment of sewers in the city of Boston:—

First (1823). "That every person who shall enter his or her particular drain into a common sewer, or shall otherwise be benefited thereby, shall be held to pay the city such sum of money as the Mayor and Aldermen shall deem just and reasonable, having reference always to the valuation of each estate connected with said drains in the assessors' books, etc."

The process seems to have been as follows: the city built a sewer in a particular street, paid for same by moneys raised in the general tax levy, and the Mayor and Aldermen deemed it necessary, in some cases, to levy no assessment whatever, and in other cases to assess the abutting estates the whole cost of the sewer, in proportion to the area of the estate and the assessor's valuation of the same per square foot.

Second (1841). "That not less than one-quarter part of the expense of constructing sewers shall be paid by the city of Boston, and shall not be charged upon those using the said main drains or common sewers."

Third (1875). "That the Board of Aldermen, in making assessments for defraying the expense of constructing or repairing common sewers, shall deduct therefrom such part—no less than one-quarter—as they may deem expedient, and assess the remainder upon persons or estates deriving benefit from such common sewer, either by the entry of their particular drain or by any remote means, apportioning the assessment according to the area of the lands benefited."

Under this law considerable latitude was given the authorities in determining how large an area was benefited by a particular sewer, in the majority of cases all estates abutting on the sewer paying three-quarters of the cost by this special tax, and in other cases three-quarters of the cost being spread over abutting estates and considerable territory not immediately abutting on the sewer, which territory in time was improved and built upon, and was again assessed for sewers made in its streets.

Fourth. In 1878 the General Statutes were amended so that "a proportional part of the charge, not already assessed, of making and repairing other main drains or common sewers through which the same discharges" could be added to three-quarters of the cost of the sewer and assessed upon those benefited, and about 1880

the city began to map out its suburban districts into drainage areas, and determine a certain portion of the cost of the main sewer built in that drainage area to be added to the cost of all tributary sewers to be built in that area; also to limit the area to be assessed in any particular street to that portion of the estate within 150 feet (soon changed to 125 feet) of the street line, and that no estate should be assessed more than once for a sewer. Under this system of assessment, which lasted until 1889, or practically ten years, and during which time the city had been actively engaged in sewering the outlying districts annexed to Boston, it is remarkable that the city was paid back, by means of assessments, less than 35 per cent. of the moneys expended in constructing sewers; the excessive cost of the mains and tributaries in the suburban districts, in proportion to the valuation of the unimproved territory, being a potent factor in encouraging abatements.

Fifth. In 1889, in accordance with the recommendation of the Superintendent of Sewers, whose theory it was that "a uniform rate per square foot of land benefited, or a uniform cost per linear foot of sewer, can be established, based upon the average cost of sewers already built, which will yield an equal amount of revenue to the city and be more equitable and satisfactory to those assessed," an act of the Legislature was passed providing for an assessment of area within 100 feet of the street in which the sewer was situated, amounting to the sum obtained by multiplying the number of square feet of land so situated by the number representing one two-hundredth part of the average cost per running foot of all the main and common sewers of the city of Boston built during the five fiscal years preceding.

The average cost of all sewers as aforesaid being conveniently determined as $4.00 per foot, this method gave an assessment of two cents per square foot; but it being found in an extremely small number of cases that by this method the city assessed more than the cost of a particular sewer on the abutters, the law was amended in 1890, fixing the rate at one cent per square foot of area within 100 feet of the street, and making an abatement of 50 per cent. on all assessments made under the Act of 1889. This law was in force until 1892, and under its provisions the city assessed only 24 per cent. of the cost of the sewers constructed.

Three radical changes in the general law of assessing sewers in the city were also made in these Acts of 1889 and 1890:—

First. That the assessments were to be made by the Superintendent of Sewers, thus taking the matter out of the hands of the Mayor and Board of Aldermen.

Second. That the power of abatement was abolished, except, of course, the appeal to a jury under the General Statutes.

Third. The assessment was a lien on the estate until the amount was paid, and its collection could not be demanded until the estate had connected with the sewer for which it had been assessed; but upon payment, 5 per cent. interest should be added from the date of completion of the sewer.

Although the city was unable, under this law, to assess but 24 per cent. of the *cost* of the sewers constructed, as I have previously stated, yet 24 per cent. of the amount *assessed* remains uncollected, and is a lien on the estates assessed, at 5 per cent. interest.

All sewers built by the city of Boston previous to 1892, with few exceptions, had been paid for with moneys appropriated for their construction raised in the general tax levy; but in 1892 the city found itself unable to raise a dollar in the tax levy, and with borrowing capacity limited by law, and the rate of taxation limited by law, and demands made for increased running expenses and all sorts of public improvements, and, in addition, realizing very suddenly that the special assessments as levied in accordance with the various laws had been returning a very small per cent. of the money expended for sewers, it was thought about time to consider the subject anew, and devise some method whereby the city could meet the ever-increasing demands for sewerage; and a law was enacted by the Legislature, which I condense as follows, and which is the sixth method of assessing sewers in the city:—

First. The Superintendent of Streets must build such sewers as the Mayor and Aldermen shall order.

Second. The expense shall be paid out of money annually appropriated by vote of the City Council, the money so appropriated to be obtained from the sales of bonds and certificates, payable in ten years from their date and bearing interest at $4\frac{1}{2}$ per cent. per annum, and payable semi-annually, the total of all amounts so appropriated in any one year not to exceed one million dollars, nor the total amount of all bonds and certificates outstanding to be more than three million dollars in excess of the sinking funds established for the payment of said debt, and said amounts not to be reckoned in determining the authorized *limit* of indebtedness of the city.

Third. That the moneys expended shall be repaid to the city by the owners of the parcels of land bordering on the sewer, to an amount not exceeding $4.00 per lineal foot of sewer.

Fourth. That said amount shall be apportioned in proportion to the frontage of the estates.

Fifth. Various provisions regarding interest and the division of the assessments into ten yearly payments, to be collected by the assessors with the real estate tax, if said assessments are not paid within one year from the date of determination.

Under this act, during the years 1892 and 1896, the city of Boston has constructed an immense number of sewers, and their cost, up to $4.00 per lineal foot of sewer, has been assessed upon the abutters, and has amounted to 60 per cent. of the moneys expended. The average assessment per front foot for the first three years was about $1.60.

But in 1894 those owners of corner estates who had previously been assessed for a sewer objected to being assessed for another sewer; so to relieve their burden, the law was amended so as to exempt their corner estates one hundred (100) feet in determining the rate per front foot, thus decreasing the assessable frontage and increasing the rate per front foot. In case of short sewers, of high cost, the assessment becomes an absurdity under this act.

I have now given you only a sketch of what has been done in the city of Boston regarding the assessment of its sewers, without discussing the particular points of weakness of each law.

The main object of the city seems to have been to supply the demand for sewers as well as it could, get the money where it could, and get a return of 75 per cent. by some means of assessment ,and it has not been very successful in getting such a return. With a population of over 500,000 inhabitants, steadily increasing; with a sewerage plant pumping on the average over 75,000,000 gallons per twenty-four hours, with over 450 miles of sewers, and with the abutters assessed under six or more different methods of assessments, with over 150 miles of streets unsewered, and many sewers that are built needing reconstruction, with an imperfect system of surface drainage and crying demands that it be perfected immediately; with the possibility that the "Greater Boston" may be realized in the near future; with the ever-increasing difficulty in obtaining money for public improvements; in view of all these complications, I hesitate, at such short notice, to consider the practicability of the application of a rental system of sewer assessments to the city of Boston.

I would state that since the above was written, I have, with the Mayor, Corporation Counsel, and Superintendent of Streets, given this subject of the rental of sewers a more thorough examination, and the result of that study has been that the Mayor has formulated a bill and submitted it to the Legislature in regard to

a rental system for the construction and maintenance of sewers for the city of Boston.

Section 3 of this bill reads as follows:—

SECTION 3. Said board shall establish just and equitable charges for the use of sewers constructed after the passage of this act, to be paid by every estate abutting on the portion of the street in which such sewers are located, and may change said charges from year to year; said board shall likewise establish just and equitable charges for the use of sewers heretofore constructed, and in determining the amount of such charges shall give all estates for which any assessment has been paid for the construction of a sewer such credit on account of such payment as in the judgment of said board would be just and equitable, having regard in every case to the amount of assessments paid and the length of time which has elapsed since such payment, and the amount of use that such estate has made of the sewer. The determination of such charges by said board shall be final in all cases.

Such charges shall constitute a lien upon the real estate, and the annual amount thereof shall be inserted in the tax bill for such estate, and be collected in the same manner and as a part of the taxes on such estate.—(C. R. C.)

SEWER ASSESSMENTS IN MEDFORD, MASS.

By T. HOWARD BARNES, CITY ENGINEER.

MEDFORD is a city within the metropolitan district of Boston, situated in the Mystic Valley division of the Metropolitan Sewerage System. Perhaps Medford is more truly situated in the Mystic Valley than any other of the north-side cities, inasmuch as she is located in about equal proportion of population on each side of the Mystic River. As a result of this location, she gets the benefit of a trunk line of the Metropolitan sewer throughout her entire extent on the north side of the river. On the south side of the river there are connections possible only at the extremes of her limits. On the whole, the situation is very favorable for short trunk lines of sewers and shallow cutting.

The population of the city, at the time the assessments were determined upon, was about 14,000. There had been no sanitary sewers built within the city until the inception of the present system, the study upon which was begun in the latter part of 1893, and construction commenced in the Spring of '94. Under a special act of the Legislature of 1893, the system has been constructed. This act provides for Commissioners, three in number, appointed

by the Mayor and confirmed by the Aldermen, they having entire charge of the construction. The same act makes provision for, or rather establishes limitations governing, the assessment of the cost. These provisions are as follows (Sec. 6, Chapter 180): "The City Council may determine what proportion of the cost said city shall pay, provided that it shall not pay less than one-third nor more than one-half of the whole cost. The remaining cost of said system shall be borne by the owners of estates situated within the territory embraced by it and benefited thereby. * * * The owners of such estates shall be assessed by said Commissioners their proportional parts respectively of such portion of the total cost of said system as is not borne by the said city as above provided. Such proportional parts shall be based upon the estimated average cost of all the sewers comprising said system, and shall be assessed by a fixed uniform rate, according to the frontage of such estate upon any street or way upon which a sewer is constructed, or according to the area of such estate, within a fixed depth from such street or way, or according to both frontage and area. * * Provided that said Board shall, on the written request of any such owner, made within said three months, apportion such assessments into such number of equal parts or instalments, not exceeding five, as said owner shall state in such request," etc.

Under this statutory direction, it became necessary for the City Council to determine: (1) What proportion should be assessed. (2) According to what rule.

It may be well to state that Medford, in common with other Metropolitan municipalities, is assessed for the fixed charges and maintenance growing out of the construction and operation of the Metropolitan trunk line. This expense is paid for out of general taxation. It may be further stated that new systems entering the Metropolitan are planned upon the "separate" system, so that the cost of caring for surface water is not represented in an assessment for the sewerage system. These facts were taken into consideration by the city government, and, after being weighed carefully, it was decided to assess but one-half of the cost upon the abutters. One of the chief reasons of arriving at this conclusion was that the item of valuation as affected in the general taxation would figure more largely in defraying the cost of construction than if a smaller part were put into the general tax. Further allusion to the item of valuation will be made later on.

The next point was to decide the method of applying the amount to be assessed. It was determined at once that the area should bear one portion, and, owing to the large number of shal-

low lots, it was deemed equitable to assess to a depth of 80 feet. In order to equalize the benefits accruing to a very shallow lot, it was further determined to assess some proportion of the cost upon frontage. It may be well to repeat right here that when the word "cost" is used the *estimated* cost is meant, based upon construction in that portion of the city which, in the judgment of the Commissioners, would need sewers within a period of say ten years. The total assessable area and total assessable frontage were computed for this district. One-half the estimated cost was divided in ratio of about four-tenths assessment upon the frontage and six-tenths of the assessment upon the area, this making $0.005 per square foot upon the area and $0.254 per lineal foot upon the frontage.

One provision of the ordinance enacted was that the Commissioners should exempt so much frontage on corner lots as was deemed to be just and equitable. It was deemed by them that an exemption upon corner lots should be made of all that frontage included within 80 feet, in the nearest direction, from the street upon which the frontage assessed was measured, and further that the frontage to be taken should be that on the longest way of the lot. Thus a lot 80 feet on one street and 50 feet on another would be assessed for 80 feet frontage and 4,000 square feet area, while one of 100 feet on two sides would be assessed 100 feet on one street for frontage, with 8,000 square feet area, and upon the other street a frontage of 20 feet, with 1,600 square feet area.

At the time this ordinance was framed there was considerable agitation of the question whether it were not better, even at that late day, to secure additional authority from the Legislature whereby a rental for the use of the sewer should be charged in lieu of the construction assessment or in lieu of a portion thereof, it being recognized that the value of the sewer to an abutter was in a measure in proportion to the amount of sewage discharged. It was also recognized that it cost the city just as much to lay 50 feet of pipe in front of a lot on which was a six-tenement block as to lay the same length in front of a vacant lot; and although it is true that the sizes of the trunk sewers have to be proportioned to carry a volume of sewage discharged by an estimated population, still, for a large majority of all the sewers built, the pipe laid has a capacity far beyond the actual requirements, simply for the reason that a less size than eight-inch is seldom used. This latter fact was found to be notably the case for Medford, because of the smallness of the drainage districts, there being some districts wherein no size larger than an eight-inch would be needed. It was also noted that the localities furnishing the most sewage were

those, as a rule, of the highest valuation; hence it was plain that the proportion of the cost of the sewers collected in the general taxation would tend to bear equitably upon these localities. Another argument in favor of proceeding under the authority already had by the statute, and which put at rest all considerations to the contrary, was the possibility that at any time a city government might reverse an ordinance which had provided for a rental system, and place, if not the entire, at least a larger proportion of the cost of the sewers in the general taxation than originally fixed upon. It may be thought that such a reversal would not be possible, provided suitable statutory authority were enacted, for a rental system. But it is also apparent that no exact rule can be made by a body so unwieldy as the Legislature and still leave that necessary latitude which it is essential that the city must have within which to act.

The method being fixed, the work of assessment was proceeded with. As had been apprehended, there were cases where there was a positive hardship, but the cases were not many, and the assessment was comparatively light. The estimated cost of the system was taken at $10,000 per mile, after being carefully calculated, with a sufficient margin for surveys, maps, and clerical work. It is interesting to note that the loss to the city in frontage on account of street intersections, rights of way, public parks, cemeteries, and miscellaneous tracts not liable to assessment averaged, for the city, about 26 per cent. Thus, while the estimated cost per foot of sewer was about $1.90, the amount assessed per foot along the street where the lots ran 80 feet or more in depth amounted to $1.308 per foot.

On December 10, 1896, there have been levied 4,085 assessments. The plan has been pursued of making a separate assessment of each sub-division of a tract. The purpose of this is to avoid complications. Where an apportionment of an assessment is desired on properties, it is frequently the case that an owner will pay on one lot and get an apportionment upon an adjoining one.

The bill for the sewer assessment is made out in the name of the owner at the date when the sewer is ordered. The date of the bill is that of the day on which the warrant for collection is sent. The bills are made out in the office of the Commissioners of Sewers, and all collections made and the necessary subsequent demands sent by the City Collector. There has been no litigation, as yet, to test any points in regard to this act. It may be interesting to state that the sewer assessment plans embody also a record of the entire work. They show the properties assessed, the number of the as-

sessment, the name of owner, frontage and area; also a profile of the sewer, showing material, foundation, etc. The title gives the dates upon which the sewers were begun and ended, the date of the warrant, the office profile to which reference is had, the note-book and inspector's record book, in which the notes were taken regarding the location and construction, and the number of the cost sheet. These plans are made upon bond paper, Weston's No. 16, 22 x 28 inches, being traced from large sectional maps of the city. Upon completion of the record plans they will be mounted. These plans also show the location of the house connections. Up to date somewhat less than one-half of the owners have applied for apportionments. Collections have been made very promptly.

SEWER ASSESSMENTS IN NEWTON, MASS.

By Henry D. Woods, City Engineer.

In 1880 a commission on drains and sewers, appointed by the city government, reported on a plan for the general sewerage of the city of Newton, with an outlet into the Charles River near the Arsenal, by an outfall sewer 8 ft. x 9 ft. The plan covered only a thickly settled portion of the city, although the outfall was figured for the whole city. The estimated cost of the work, as planned at that time, was $465,000. No progress was then made beyond the presentation of the report.

In 1890 the city engineer, the late Albert F. Noyes, reported on a general system of sewerage for the whole city, in connection with the Metropolitan sewer, which was soon to be extended into the Newton territory. This plan was laid out on the separate system, on account of the necessity of all the sewage being pumped at Moon Island before being disposed of. The plan proposed contemplated some 130 miles of sewers through the various streets of the city, and called for a sub-soil or ground water drain to be laid at the same time as the sewers, and below them, for the purpose of drying out wet land and cellars, and also to relieve the pressure of ground water on the sewers, and prevent, as much as possible, any infiltration of water into the sewer pipe, the object of this being to reduce to a minimum the flow of sewage which would eventually have to be pumped by the Metropolitan system. As stated in the report of the City Engineer, it was intended that an entire separate system should be laid out, to care for the surface water through the various streets. This would be built entirely

independent of the sewer, and in fact it was not until 1892 that a general report on the surface drainage of Newton was presented to the Board.

The estimated cost of the 130 miles of sewers as laid out by the plans and reported by the Engineer was $1,755,000, or an average of $2.56 per running foot. As stated in the report, the cost of the trunk lines varying in size from 18″ to 24″ pipe, and 24x30 in. brick, was about $430,000.

As soon as possible, after the report had been accepted, construction was commenced on the system there recommended, and this brought the question of sewer assessments to more definite consideration, and towards the end of the year an ordinance was passed which called for the whole cost of the sewer system as laid out through the city of Newton, to be assessed on the abutting property. The average cost of the whole system was estimated to be $2.56 per running foot, and the assessment of this cost was apportioned 4-10 on the relative frontage and 6-10 on the area of abutting property back to 180 feet from the street line. The rates under this ordinance were 60 cents per front foot and 6 mills per square foot of area, with an exemption on corner lots of the first 60 feet on a second street. This ordinance brought up a very heated discussion and several public hearings were given before the City Council in relation to the matter, it being claimed, especially, that the whole cost should not be assessed on the abutting property, but a portion of it should go into the general tax levy.

As an actual fact and as recommended in the City Engineer's report, the city was to pay all the cost of maintenance, all the charges in connection with the Metropolitan sewer and outlet, including pumping and also all the cost of surface drainage. The last item is very large, and in cities using the combined system, becomes a part of the cost of the sewer system, and increases the cost many times for the reason that the pipes or sewers must be made many times larger on account of surface drainage than would be required for house sewerage only; so that even were all the cost of construction of the Newton sewer system charged to the abutting property, the city at large would still bear a very large portion of the cost of disposing of the refuse water (surface drainage, sewage and ground water). However, before any assessments had actually been made under the ordinance of 1890, a new ordinance, September 12, 1892, was ordained, wherein the city was to bear one-quarter of the expense of construction of the sewer system, and the rate of assessment became 50 cents per front foot and 6 mills per square foot, with the corner lot exemption of 100

feet frontage on the second street. It will be noticed, as stated above, that the main trunk line of sewers were estimated to cost about one-quarter of the total estimated cost of the system, $430,-000, more or less, out of $1,755,000, so that the new ordinance practically assessed only the cost of the local sewers on the abutting property, leaving the city to pay the cost of all the trunk lines. In the meantime, construction having been going on for nearly two years, it was found that the cost of the work would exceed somewhat the original estimate. By a new estimate made by the City Engineer the average cost per foot was found to be $2.685, and this was the rate on which the assessment was based in the new ordinance.

The assessments were sent out that year under this ordinance, but much complaint was still found, the rate of 50 cents on frontage being considered a great hardship. The next city government reconsidered the whole matter and finally on June 26, 1893, made a change in the ordinance by which the city assumed one-half of the cost of construction, the other half being borne by the abuttors, with the rates of 15 cents per front foot, and 5½ mills per square foot, back to a distance of 180 feet from the street, the question of corner lot frontage being left to the discretion of the Board. This is the ordinance in force at the present time, and it has been the decision of the Board that all frontage should be paid for at the rate of 15 cents whether on one, two or three streets. If I remember rightly there is one case in the city where a lot borders on four different streets, and this does not happen to be a corner lot either, but more in the shape of a cross.

With regard to the working of the ordinance, there does not seem to be a very large amount of kicking, not more than would be naturally expected against any form of sewer tax. Tax-payers always have the option, when the assessment bill is sent them, of applying within a certain time to have the amount apportioned into ten or less annual payments, they paying interest on amounts due. This privilege is very generally availed of, and as far as the finances of the city are concerned, increases to a certain extent the amount of money that the city is obliged to borrow for construction, for, by rights, money coming in from assessments should be used over again to pay the expenses of current construction rather than to require the city to borrow outside money to do this work.

No entrance fee is charged in Newton, the bill of assessment covering all the charge made on each piece of land. This might be considered somewhat of a hardship from the fact that unimproved land pays the same as land which is built upon and actually

using the sewer. Of course, as a rule, the assessment on unimproved land is apportioned, but still the amount is the same for the same sized and shaped lots as a lot in the village which may be occupied by a tenement or a brick block.

In cases where a lot with a house upon it is beyond the 180 foot line and it is desired to connect it with the sewer, the ordinance calls for payment of a reasonable sum to be determined by the Mayor and Aldermen. It has been customary in this case to fix this sum to correspond to an area of about 50 feet all around the building, more or less, according to the location, and to tax it at the $5\frac{1}{2}$ mills per square foot rate, so that if at any time a new street is built, or a sewer is built on a present street contiguous to this lot, the amount already paid for sewer assessment can easily be deducted from the area assessment due on the new sewer. This seemed to be the simplest and most equitable way to arrive at a charge on buildings outside of the ordinance limit.

One peculiar case which has come up in Newton and is liable to come up in many places where large estates still exists, is the one where the building which is to be connected with the sewer is beyond the 180 foot limit, or sets on the line, and the sewer assessment has been levied on all the land within 180 feet. Great objection has been made to paying an additional assessment, and the matter has had to be waved at the present time, but should the estate be opened up with streets there is no doubt that an area assessment on the new street could be applied to the land on which the house is standing and could be collected under the ordinance.

It has been customary where the end of the sewer stops in front of a lot to assess on either side of the street to a right angle line 50 feet beyond the end of the sewer, unless this line strikes a lot before which the sewer does not pass. The reason for this is that in many cases a house is built within 50 feet of the end of the sewer and can be connected into the manhole (and in fact in many cases this has been done) when there is no liability of the sewer being built any farther, this very often being a summit as far as sewer grade is concerned. Some definite line has to be decided on for this purpose, as a house might be built just opposite a manhole or the end of the sewer, and if a two-tenement house, the second tenement might be entirely beyond the end of the sewer, yet both be connected through the same trench.

I might state here that house connections are mostly made by the city, the actual cost being paid by the abutter, a deposit being made by the abutter on the estimated cost before the work was commenced. The ordinance allows the work to be done by

licensed drain layers, but there have been but two or three licenses granted in the last five years, none being applied for.

With regard to the method used in Brockton and described in Mr. Snow's paper, it would seem as if the charge which is applied to meter rates of water service would be liable to cause considerable trouble unless parties go to the expense of having separate meters applied: All water used for lawns and gardens, and in many cases used for washing carriages, would affect the charge for the use of the sewers, and it would seem as if this would bring in one more element of dissatisfaction and complaint. In establishing a rate on this basis so many elements of uncertainty have to be considered, that, as Mr. Snow states, the rate will have to be changed once in a while even at long intervals, and it seems as if the keeping of the accounts in the Treasurer's office would be considerably complicated, owing to the fact that it would be necessary from time to time to adjust the income with the expenses. Where only the frontage and area are charged the whole amount to be collected can be figured quite closely by going over a plan of the streets as far as laid out, and the amount collected later on for streets to be laid out will be balanced, to a more or less extent, by the cost of construction in those streets and to them where they are in distant localities.

In the city of Newton, when the ordinance changing the rate was passed, it was necessary to abate all the old bills and readjust them to the new rates, which was a matter of considerable clerical work and necessitated many changes on the books.

SEWER ASSESSMENTS IN MALDEN, MASS.

By George A. Wetherbee, City Engineer.

I cannot help feeling that Mr. Snow has contributed, in his interesting and instructive paper, a very valuable addition to sewerage literature. Although I am not prepared at this moment to agree with him entirely in regard to the rate system as a means of satisfactorily solving the problem of sewer assessments, whether as a part of the assessment or the whole, I am satisfied that his investigation is in the right direction.

As the method adopted by the Commissioners in Malden resembles, in a way, the method designed by Mr. Snow, with the addition of perhaps some interesting peculiarities, it might be well to give a brief description of our method.

When the wise men of Malden first considered the question of sewer assessments, or, more properly speaking, the method of raising money for the liquidation of the sewerage debt, the question of a yearly rental, suggested, presumably, by the almost universal method of paying a water debt, was so favorably considered that a special act for our sewerage system was the result, of which the following sections form a part:

Chapter 188, of the Acts of 1890. An act to provide for the building, maintenance, and operation of a system of sewerage disposal for the City of Malden.

Section 2. The City Council may provide by ordinance that owners of estates on which there are buildings situated upon any street or way through which a main drain or common sewer has been constructed shall construct and maintain such drains through their premises, as may be necessary to conduct the sewage from said estates, and shall enter said drains into said main drain or common sewer, provided the grade or level of said estates is such that said sewage can be drained into such drain or sewer.

Section 3. The City Council may, by ordinance, establish annual rates to be paid by the owners or occupants of estates upon any street or way through which a main drain or common sewer has been constructed, provided the grade or level of said estates is such that the sewage from said estates can be drained into such drain or sewer; and may change the same from time to time. Unimproved estates may be excepted, either while unimproved or for a term of years, or such discrimination may be made for the relief of said estates in fixing the amount of said annual rates as may be deemed equitable. The City Council, by ordinance, shall fix the sums which such owners may pay in lieu of said annual rates, and said sums shall, upon the written request of any of said owners, be apportioned in three equal parts; and one of said parts with interest thereon from the date of said apportionment shall be paid in each of the three years next ensuing.

Said annual rates and said sums to be paid in lieu thereof shall constitute a lien upon said estates, and may be collected in the same manner as taxes upon real estate or by an action of contract in the name of the city. Said lien shall continue for two years after said rates or sums to be paid in lieu thereof have been committed to the collector for collection, and when said sums are to be paid in instalments shall continue for two years after the last instalment has been committed to the collector for collection.

Section 4. The receipts from said annual rates and payments made in lieu thereof, after deducting expenses, shall be applied first

to the payment of the interest upon the scrip or bonds issued under the authority of this act not otherwise provided for; and the balance shall be set apart to meet the requirements of the sinking fund for the payment and redemption of said scrip or bonds, as provided by Section 9, of Chapter 29, of the Public Statutes. If said receipts shall be insufficient to pay the interest on said scrip or bonds and to meet the requirements of the sinking fund, as provided by said Section 9, the deficiency shall be raised annually by taxation.

If in any year there shall be an excess of the sum necessary to pay said interest and to meet the requirements of the sinking fund for said year, the surplus may be applied toward the payment of the sums which the city is required to pay by the provisions of Chapter 439 of the Acts of the year 1889. Said sinking fund shall remain sacred and inviolate and pledged to the payment and redemption of said scrip or bonds, and shall be used for no other purpose. The provisions of Sections 10 and 11 of said Chapter 29 of the Public Statutes shall, so far as applicable, apply to said sinking fund.

Chapter 443. 1895.

Section 9, of Chapter 245, Acts of 1892, shall not be obligatory upon the City of Malden.

When the Commissioners were ready to formulate their plans for assessments, I sent them the following communication:—

"Feeling that you will shortly be called upon to consider the question of sewer assessments, I beg leave to submit a few suggestions.

"It appears that there are quite a variety of methods of apportioning the cost of sewer construction, enjoyed by the various cities and towns, as will be seen by the list of questions and answers which accompanies this communication. The front foot, and the area with a limiting distance from the street are the most common; either of these methods, separately, presents an injustice to the abutter. With the front foot, the man with a lot of 200 feet frontage and 60 feet deep, pays twice as much as the man with a lot of 100 feet frontage and 200 feet deep; yet in the first case there is not necessarily twice the benefit; with the area plan the injustice is the same only it works against the other man, the man with the 200 feet frontage pays less than the man with the 100 feet frontage.

"A combination of the two methods has been adopted by several cities as being the most equitable way of treating this problem, the proportions being 4-10 by frontage and 6-10 by area, with an allowance for corner lots; this, of course, is purely arbitrary and

not strictly scientific, but to devise a method which shall meet and answer every objection is practically impossible, and I should call that the best method which embodied the principle of fair play, and simplicity in application, in the highest degree.

"The usual allowance for corner lots is, of course, an arbitrary one; it is a justifiable attempt to avoid the appearance of double assessment. In Newton 60 feet on the side street is not assessed by frontage; the limiting distance from the street for area in Newton is 180 feet; in other cities from 100 to 150 feet. It is impossible to avoid all appearance of unfairness in the treatment of corner lots unless you make a greater concession than the average use of such lots would justify.

"I think for Malden the limiting distance from the street for the area assessment should be 100 feet, and the allowance on corner lots be the same as in Newton; if we make the limiting distance, say 150 feet, then the owner of a 100-foot lot secures the benefit of a smaller rate per square foot than it seems to me he is entitled to; with the limiting distance 100 feet you may say that the owner of an occasional deep lot pays no more than the owner of the 100-foot lot, and yet he enjoys a prospective use of the sewer greater than his neighbor with the 100-foot lot.

"The judicious subdivision of land in Malden will make the distance between streets about 200 feet, and the occasional deep lot will probably be owned by the individual whose income makes possible the unrestricted enjoyment of his back land as a garden. Back land will in very few cases be benefited by a separate system of sewerage unless it be developed, this in most cases will necessitate a lateral sewer with its accompanying assessment, so the city will certainly lose nothing by making the limiting distance 100 feet, and the owner of the deep lot will be simply paying, like his neighbor with the shallow lot for the benefit enjoyed, namely, house drainage.

"The question of rental or annual rate for the use of sewer will probably be considered by your Board. It seems to me that if this method is considered less of a hardship to the tax-payer, the same reasoning will apply to the apportioning of the assessment into ten annual payments. (Chapter 320, Acts of 1893.) The sewer tax will undoubtedly be a burden to the poor man if made in one payment, but, generally speaking, his assessment will be relatively small, and, if made in ten annual payments, would hardly be called a hardship. It would be a fair statement to say that under the separate system of sewerage adopted in Malden the question of apportionment of cost between the city and the owners

of land benefited by the sewers does not arise, as the city, in its corporate capacity, receives no benefit from a system which provides for house drainage only, so the entire cost might be justly assessed upon the land; but Section 9 of Chapter 245, of the Acts of 1892, says, 'that the city shall pay not less than one-fourth nor more than two-thirds of the estimated cost of construction.'

"I have copied several of the statutes for your use, printing in capitals the sections most affecting this question. The estimated cost of the sewers in Malden is $1.93 per linear foot. Estimating the total length of system to be 419,590 feet, and the total length which can be assessed to be 315,490 feet, then we have 419,-590×$1.93=$809,808.70; divided as I have suggested, four-tenths by frontage and six-tenths by area, we have $809,808.70×0.40= $323,923.48÷315,490=$1.02, and $809,808.70×0.60=$485,885.22 ÷55,962,000 square feet =$0.0087. $1.02 is the portion which can be assessed per linear foot of street; then one side of the street will be $0.51, and the area at $0.0087 per square foot for 100 feet deep will be $0.87; total equals $1.38 per linear foot, if we assess the whole cost; if we assess approximately one half the cost, say 26 cents per front foot and one half-cent per square foot, it will equal $0.76 per foot assessment."

After what I am constrained to believe was an industrious handling of the subject, and governed in part by the legal advice of the framer of the above act, the following charges for sewerage benefits were fixed:—

For unoccupied land, $3.00 for each 50-foot frontage, or six (6) cents per front foot. For single dwellings, $5.00 where the water rates do not exceed $10.00 per annum and twenty (20) per cent. of the water rates charged in excess of that sum, provided that the maximum rate for single dwellings shall be $15.00. Dwellings not using city water to be assessed rates to be determined by the Board.

And, in accordance with the requirements of said act, the Board of Street Commissioners have fixed the sums which owners of estates may pay in lieu of said annual rates at $1.00 per linear foot of frontage which assessment will cover, not exceeding one hundred (100) feet in depth; corner lots having a depth of more than 100 feet to be assessed at same rate for all frontage on second street in excess of said 100 feet. Land not assessed under the above provisions will be subject to future assessments.

The following notice was then sent to each and every person owning property on streets wherein sewers had been constructed:—

MALDEN, September 15th, 1896.

You are hereby notified that the Annual Sewer Rate for the year 1896 of \$................ has been established and assessed on your estate No. ....Street, and the same is now payable to the Collector of Taxes, City Hall.

By order of the Board,

GENERAL INFORMATION.

Owners of Estates on Streets where the Common Sewer has been constructed, must pay either an annual rate or a fixed assessment. Failure to connect will not relieve from payment.

Annual rates as established by this Board are now payable at the office of City Collector.

Owners of estates desiring to pay a fixed sum in lieu of Annual Rates must return their annual rate bills to this office at once.

If it is desired that the fixed sum or assessment be apportioned, the Board of Assessors must be notified in writing within thirty days from above date.

Interest will be added to Rate or Assessment bills remaining unpaid October 15th.

The effect of this notice was curious. The department was overrun with people asking questions which were fully answered in the notice. Some people paid the annual rate under the impression that this payment settled the whole business; quite a number were of the opinion that they had paid all the city could reasonably expect when the house connection was made.

Payments have been made approximately as follows: 919 have paid the annual rate; some of these have since paid the whole assessment, preferring to lose the amount of the annual rate already paid and close up the account; others have signified their intention of paying the whole assessment before the second rate is due; 576 have paid the whole assessment, and 1,640 have had the assessment apportioned. This result would seem to indicate that where it is optional with the property owner the assessment will be paid instead of the rate. The average annual rate in Malden is about \$7.00; the average lot is about 50 feet front; the owner finds that in ten years the amount paid in annual rates will amount to about \$70.00.

To be sure, he revels in the luxury of a hired sewer, but he must continue to pay his rent, and there are no legal difficulties in the way to prevent his landlord from raising the rent. The owner also discovers that by paying the assessment in lieu of the rate and having it apportioned in ten annual payments, with interest at 5 per cent., at the end of ten years he will have paid about \$70.00; but in the latter case he has paid for his sewer in full, and feels that he owns it. It would certainly seem reasonable, under

the present condition of things, to predict that about 90 per cent. of the people will pay the assessment instead of the rate; the other 10 per cent. will be the owners of large estates, where the rate capitalized will be much smaller than the front foot assessment; but if the Commissioners, during the coming year, make a rule, which I think is quite probable, limiting the frontage which the rate is to cover, then it is quite possible that every one will pay the assessment, and the rate system will simply become a pleasant or an unpleasant memory. I am under the impression that the rate system alone, or as applied in the city of Brockton, would not have been pleasantly received by the people of Malden.

So many cities and towns in our immediate vicinity have made the single assessment, though it may not be as logical or equitable, it carries with it the simple fact that the agony is over with the one payment, or, if apportioned, the end can be seen.

This, I think, would create the desire with our people to be treated in a similar manner.

SEWER ASSESSMENTS IN MARLBORO, MASS.

By James F. Bigelow, City Engineer.

I was very much interested in the paper presented by Mr. Snow on the subject of sewer rentals, not only for the careful manner in which he presents his subject, but because it recalls very forcibly to my mind the experience of my own city a short time ago in dealing with this same problem.

Just at the present time, when so many towns and cities throughout the country are considering the matter of sewers and sewage disposal, this subject of assessments, it seems to me, cannot be other than one of very great interest, and one that should receive very careful consideration.

We all know that when the conditions of a city or town are such that some system of public sewers becomes necessary for the health and comfort of the people it is a very easy matter to get the necessary legislative rights to construct such a system of sewers and to issue the proper notes or bonds (as is generally the case) to meet the cost of its construction. But the paying of the notes or bonds by the estates receiving benefit from the sewer is another thing. The people are always ready and willing to pay their just proportion of any necessary public improvement; still, they want to feel that they are receiving their money's worth. On that point

alone, in my opinion, is where the whole trouble of sewer assessments lies.

The laws of this State, prior to the year 1892, as Mr. Snow has said, provided various ways by which estates receiving benefit from a particular sewer or system of sewers might be assessed for such benefit. He also points out the different assessments allowable under the law and the difficulty in deciding upon a system of assessing, on account of the great diversity in shape and positions of different estates, that would distribute the tax justly and according to the benefit derived.

The city of Marlboro, after considering the various methods of sewer assessments, and finding substantially the same difficulty with them in making a just and equitable assessment, as cited by Mr. Snow, finally decided upon a form of rental similar in some respects to the Brockton plan. This rental is based upon the amount of water delivered into the sewer from each estate, and is substantially as follows:—

For all estates taking water by metered service, other than manufacturing establishments, at the rate of seven and one-half cents (ten cents a thousand gallons) for each one hundred cubic feet of water delivered to such estate during the current year. Provided, however, that when the quantity of water so delivered shall be less than fifty-three hundred and thirty cubic feet (40,000 gallons), the charge shall be four dollars for such year; and provided, further, that estates taking water by unmetered service shall pay six dollars for the current year; and provided, further, that when a sill cock is used on estates taking water by metered service a discount of fifteen per cent. shall be allowed, except that in no case shall said discount be allowed to reduce the yearly charge for such estate below the minimum price of four dollars.

For manufacturing establishments, seven and one-half cents for each one hundred cubic feet of water delivered to such establishments during the current year, less a discount of sixty-five per cent., except that in no case shall said discount be allowed to reduce the yearly charge for such establishment below the minimum price of four dollars.

Ordered, That all said rental charges shall be due and payable semi-annually on the first Monday of January and July, and if any such charges remain unpaid for sixty days after becoming due, the Collector of Taxes shall proceed to collect the same according to law.

The above schedule of rates is based on the assumption that all the buildings on the line of the sewer are to be connected. At the present time there are about 1,700 buildings, of which about three-quarters are now connected. The sum collected each year from such rates amounts to about $9,000, and is enough to pay one-half the sinking fund for the sewer bonds, one-half the annual expense of interest, and the cost of maintenance of the system.

The other one-half of the interest, sinking fund, and maintenance is made up from the general tax levy. Under the above plan three semi-annual rentals have been collected, and the plan thus far has given very general satisfaction.

Situated as this city is, I see no reason why it will not continue to work all right. The question might be raised that to assess one-half the yearly cost by general taxation was too much, and in some cases it might prove so. I think, however, it depends entirely on circumstances, such as the cost of the entire system, the amount of the benefit to be derived, and the proportion of the general tax represented by the district assessable for the sewer system, compared with that outside of it. These are points that must be decided entirely by local circumstances.

While we do not claim that our system is by any means perfect, we consider it the best, all things considered, that has yet been brought to our notice.

SEWER ASSESSMENTS IN PAWTUCKET, R. I.

By George A. Carpenter, City Engineer.

I have been very much interested in the paper prepared by Mr. Snow, and I agree with him when he says that "Up to the present time sewer assessments generally have not been made proportionate to benefits received."

His plan of meeting a portion of the cost of construction and maintenance by an annual rental based upon the consumption of water seems to be a just and proper way of making those to whom the system is of the most benefit pay a larger proportion of the expense, but how will it work in practice?

Will it be any hindrance to a more general use of the sewers after they are constructed?

We all know how dilatory people are in making connections with the sewers, and, if a system of annual rental should tend to decrease the number who would otherwise avail themselves of this privilege, I believe that it would be better that a larger proportion of the cost should be met by a general tax, even though such a system be not ideal.

The result, in this particular, in Brockton, will be watched with interest.

In 1895 I was interested in ascertaining how generally the sewers in the city of Pawtucket, R. I., were being used, and found

that in a district covered by seven miles of sewers but 54 per cent. of the buildings that could be drained had been connected with the sewers.

The following figures, which show the working of the more general law of assessment based upon frontage and area, may be of interest at this time:—

In 1878 the Town Council of Pawtucket was directed by statute to assess abutting property at the rate of 50 cents per front foot, and 1 cent for each square foot of abutting estates lying between the street and a line not exceeding 150 feet distant from and parallel with such street, and property was assessed in this manner for the first two sewers built.

Six years later this law was amended so as to read, "At a rate *not exceeding* 50 cents for each front foot * * * and *not exceeding* 1 cent for each square foot of such estates between such street and a line not exceeding 150 feet distant from and parallel with the line of such street."

Availing themselves of this privilege, the Council, from 1884 to June 30, 1886, assessed property at a rate of 50 cents per front foot, and one half-cent per square foot of area 100 feet in depth.

During these two years 4.71 miles of sewers were constructed and assessments amounting, in round numbers, to $43,000 were levied. This makes the average assessment rate $1.73 per foot of sewer built, and I regret that I have not the figures showing the average cost per foot of the sewers for this period.

On June 30, 1886, the assessment was changed to 25 cents per front foot and one half-cent per square foot of area 100 feet in depth, under which system assessments are still levied.

Rebates were made upon the $43,000 already assessed, which reduced the amount collected to $31,500, or $1.26 per foot of sewer constructed.

Since 1886, 25.02 miles of sewers, ranging in size from 8″ in open cutting to 87″ in tunnel, have been built at a cost of $518,-267.00, and assessments amounting to $152,338.48 have been levied. This is an average assessment of $1.15 per foot of sewer, and has paid but 29.39 per cent. of the cost of construction, the remaining 70.61 per cent., together with the cost of maintenance and the interest on the sewer bonds, being met by the general tax.

The reason for the reduction in the amount of the assessment was, I am informed, because it was found, when some of the smaller pipe sewers were constructed, that the assessment more than equaled the cost of the sewer, and so, without considering the ultimate cost of the completed system, the rate was at once reduced.

Upon 4.68 miles of sewers constructed in 1894 and 2.84 miles in 1896 the assessments were 35.39 per cent. and 35.92 per cent. of the cost, while upon 3.53 miles built in 1895, some of which were large and expensive, the assessment was but 16 per cent. of the cost.

From experience in a city where the cost of every improvement excepting that of sewers is met by the general tax, and where the demands of the citizens for these improvements rapidly multiply as the city increases in size, resulting in a large debt and in an increasing tax rate, I am more and more drawn to the opinion that a larger proportion of the cost of not only sewer construction and maintenance, but other public improvements as well, should be met by assessment upon property which is especially benefited.

This would result not only in a decreasing cost to the city for improvements made, but would, I think, decrease the demand for such improvements, which are so numerous when some one else pays the larger part of the bill.

The question of what proportion of the cost should be assessed upon property especially benefited, and in what manner such assessments should be made, is one which engineers may well study and discuss.

SEWER ASSESSMENTS IN FALL RIVER, MASS.

By Philip D. Borden, City Engineer.

The city of Fall River has never made assessments for use of sewers.

The question has often been considered, and several reports made thereon, but no action has ever been taken by the City Council, although the ordinance says: "The Mayor and Aldermen, with the concurrent vote of the Common Council, shall, whenever any main drain or common sewer shall have been constructed, forthwith fix upon a reasonable sum of money which every person entering a private drain into such main drain or common sewer shall pay to the city for such privilege. The permits granted by the City Engineer, as heretofore provided, shall be upon condition of payment of said sum."

Every person receiving a permit to make sewer connection signs, in the City Engineer's office, an agreement reading as follows: "In consideration of this permission, I further agree to pay

into the City Treasury, on demand, such sum or sums of money as the City Council may assess for the same."

January 1, 1896, 3,396 private drains had been connected with public sewers. The number to January 1, 1897, will be about 3,800. The large increase during the year is accounted for by the fact that the Board of Health, acting under the provisions of Chapter 132, Section 1, of the Public Statutes of 1890, have issued orders to all parties owning premises, on a street through which a sewer has been laid, to make connection with said sewer immediately.

Their reading of the act does not confine them to premises on which a nuisance exists, but applies to *every estate abutting on a sewered street.*

Our City Solicitor has given an opinion that the agreement to pay the sum assessed for the privilege of entering a sewer is binding only for six years. This raises one complication in the matter. Another comes from the fact that the Mayor and Aldermen have not complied with the ordinance, which says they *shall forthwith* fix upon the sum to be paid, etc.

Another point is raised by parties who have paid taxes, a portion of which were used to construct sewers more than six years since, that it would be *unjust, and therefore illegal,* to assess them for entering a sewer simply because it was built within six years, and exempt the person on an adjoining street who had the influence necessary to have a sewer built in front of his premises ten years ago.

One member of the legal profession, now sitting on the Bench, claimed that he could not be compelled to pay an assessment for sewer privileges enjoyed in the house purchased by him, as he had already paid it, having figured the house at an increased valuation after finding it had sewer connections, and he accordingly paid more than he would without such connection, and figures the difference between such sums as his "sewer assessment." The property was bought at a bankrupt sale, which gives him no chance to recover from the seller.

Another claim is made that the assessors of taxes do or should figure an added value to real estate having drainage facilities, thereby increasing the amount of their tax and removing the much-talked-of injustice of building sewers from the general tax levy.

The question will probably be taken up early in the coming year, and it is hoped some plan will be adopted. The plan most approved is that of making an annual charge. As the amount of

sewage to be carried out depends largely upon the amount of water taken in, it has been proposed to make a price for sewering the property depend upon the water bills. Just how to connect the two has not been decided, as the amount of water used by different families varies greatly.

Much of the property in this city is owned by parties who never have any large sums of money available, and the plan of making an assessment of $100 in full for the privilege of using a sewer would be strongly opposed by many who would willingly accept the annual charge of $7.50 or $10.

Another cause of complaint, but one for which the city is in no way responsible, is the fact that the cost of carrying a drain from the sewer to the line of street will vary from perhaps $150 in solid ledge to $20 in gravel. The only way to equalize this would be for the city to carry the sewer to the property line, making the charge for this work the same in every case.

PROFESSIONAL SPIRIT.

By Donald W. Campbell, Member of the Denver Society of Civil Engineers.—Presidential Address.

[Read before the Society, January 12, 1897.*]

As your President is expected to make, during his term of office, at least one address to the society, on a subject pertinent to the well-being of our profession, the title of "Professional Spirit" is selected for the address I now make before closing my term, hoping to stimulate that spirit by bringing to your notice the high standards set up by those societies which, in former times, claimed to be the only "professions."

In early times the recognized professions were three only—Divinity, Law, and Arms. In the eighteenth century Medicine was generally recognized as a learned or liberal profession, but recognition was secured only after a long struggle, traces of which still exist, where Arms and Medicine come in contact. During the present century Engineering, or the application of science to construction, has asserted its right to be regarded as a learned sister, and has not escaped the opposition of its elders. We, however, claim that learning and skill in the sciences which form the basis of construction, and the practical application of these sciences in "subduing the materials and forces of nature to the service of man," is an occupation entitled to and worthy of professional status.

Defining science as being observation of the processes of nature, orderly and systematic record of observed facts and sequences, and deduction of principles from the facts and sequences so recorded, a profession is usually considered to be an occupation which requires a liberal and broad education, and special learning and training in the sciences required, and the "profession" made by its members to be a profession of that skill and training. I will endeavor to demonstrate that the profession made, whilst embracing skill in the basing sciences and the practical application of them to the affairs of men, includes another important declaration, viz: a profession of obedience to the highest moral code of the country and age in all business dealings.

The origin of the professional idea in Europe, and its development in England, whence we derive it, will be briefly outlined, and, as the Church claims the leading place, this will be considered first.

*Manuscript received February 8, 1897.—Secretary, Ass'n of Eng. Socs.

That churchmen were the conservators of learning, from the fall of the Roman Empire until the revival of learning in the fifteenth and sixteenth centuries, will be generally conceded, and the profession made by the clergy is all that interests us in this connection. In this profession, besides that of faith, etc., there is a promise to obey the moral precepts of Christianity and the canons of the Church, and obedience to these obligations is, at least in theory, necessary to the continuance in the priestly office, and this is true of all modern branches of the Church.

The profession next in rank is Law, and it is to the precedents of this profession that we must look for guidance in most matters of etiquette and for the development of professional ideas. In the Republic of Rome, the Juris Consulti, or men learned in the law, were eminent citizens of patrician birth, ex-magistrates and officers of State, who, in old age, actuated by public spirit or a desire for honorable employment, advised the clients, or "hearers," but the relations between the litigants and the lawyer were the reverse of the modern relations. The man learned in the laws and customs of the Republic was the "patron," and the client, or "hearer," was a dependent foreigner or humble citizen, who asked advice and guidance as a favor. The practice of giving opinions as to the laws and methods of obtaining justice was soon regarded as an honorable and praiseworthy way of spending the evening of life, and no compensation was given for the service rendered; indeed, a tender of money would have been deemed an insult, and the service was given from love of the work, and was accepted with gratitude. After the establishment of the Empire, Augustus, when remodeling the forms of government, felt constrained to recognize the Juris Consulti, and brought them within his scheme of government by making appointment to their ranks a prerogative of the Emperor, thus virtually licensing and controlling the profession. Long before this was done, the taking of fees was a common practice, but this was never done openly or after service had been given, but was given in advance, to secure the services of selected men, and the fee was considered an "honorarium" or gift, and no contract of any kind could accompany the tender.

It may be considered that the development of fee-giving was a necessary consequence of the primary conditions of life. All men must eat, drink, and be protected from the weather, and even ascetics require something. Diogenes had a tub, which he either earned, received as a gift, or stole. The method of development of legal fees has been a benefit to all sellers of mental labor who have lived since, as it constantly indicates the fact that there can be

no tangible material delivered in return for the money paid, but that the whole transaction is one dependent on the honor of the fee-taker.

The Church was the means of conveying the ideas of the Roman lawyers to all parts of Europe, and the early lawyers of England were priests, the law schools being the monasteries and priories. Subsequent to the Norman conquest there was a conflict between the native and the foreign priests as to whether the Roman or common law should prevail. It was eventually decided in favor of the native, or common, law, and in the reign of Henry III laymen were admitted to practice in the King's Courts, and subsequently priests were forbidden to practice, but this law was not rigidly enforced, as the Chancellor was always a cleric, until Sir Thomas More was made the first Lay Chancellor by Henry VIII.

It is probable that the early clerical practitioners often gave their services to their dependents and others free, and that the relations between them and their clients were practically the same as those of the early Roman Juris Consulti with clients, and that the same change developed in England, from the same necessity, as in the Roman Republic. We know that in early times the taking of a fee was a delicate matter, so distasteful to the recipient that, although from necessity or avarice he must take one, it was customary to drop it surreptitiously into a pocket in the back of the coif worn by pleaders. This legal fiction is maintained in England to this day, and, although a modern barrister might fare badly if he depended upon the few coins he might find in his coif on disrobing, the pocket is still in the junior counsel's stuff gown, but the modern practice is to tender the "retainer," honorarium, or fee to the barrister's clerk, and not in the presence of the barrister; if insufficient to secure his service, or if he is from other reasons unable to take the case, the clerk returns the money, and whatever reason is given, it is the clerk's reason, as the lawyer is in legal ignorance of the transaction. The barrister, however, might take the fee and do nothing, as it is an honorarium or gift, which could not be recovered at law, and the return of the sum given is purely a matter of honor. On the other hand, a barrister cannot sue for service rendered; the whole engagement is an affair of honor and conscience only, and the reasons for this have been ably expounded by many able law-writers, too voluminously to be quoted, but the basing idea, beyond the dignity of the barrister as an officer of the Court, bound to obey its rulings on honor, is the inability of any man to measure a mental performance. By

the rules of the Courts and the traditions of the profession, the lawyer is bound to make his client's case his own, and to do for him all that he would do for himself under like conditions. If he took a fee and then did nothing, the barrister, if arraigned, might plead that under like conditions as the client *he* would do nothing, and the falsity of this could not be proved; therefore, the whole matter is dependent on the conscience of the lawyer. All the Courts of Europe and all countries settled by Europeans, both under Roman and common law, have maintained the right to disbar or expel their pleaders for mere immorality not amounting to crime, and this right is frequently exercised. In our country the laws and the rulings of the Courts have modified many stiff old customs, so that lawyers can sue for service rendered, but the ideas on which the old customs are based are upheld, and faithful attention to the business of clients is enforced, both by the Courts and by professional associations.

In the profession of Arms the professional spirit has had great development in modern times. As strife or war is inherent in human nature, it is probably the oldest of the professional occupations, but the study of the sciences as an aid to warlike operations has been systematic only since the establishment of standing armies and navies. The arts of shipbuilding, entrenchment, and fortification were the first on which the study of science was applied, and in this application, called into service by the exigencies of strife, is to be found the genesis of our own profession. Military engineering was the babe, now grown to the well-developed general engineering body of to-day, and the affix "civil" simply designates the non-military division of the profession, now the most important to the progress of civilization.

The history of Medicine need not be reviewed, as this profession is like our own in one respect, viz: the total absence of a controlling authority having power to supervise the conduct of its members, but we can learn a lesson from its modern development, greatly aided as it was by the systematic fight made by all schools to regulate admission to its ranks. Whilst voluntary associations of surgeons and physicians, of several schools and systems, cannot control the morals and practice of men who have been once regularly admitted, they can expel from these associations all who violate the code of morals and etiquette prescribed by a majority of their members, and these associations have, by systematic appeal to Legislatures, persistently maintained for many years, succeeded in getting laws passed in nearly all civilized countries prohibiting the practice of medicine or surgery by any one who does not hold a certificate of qualification issued by a regular school.

In the practice of law the basing sciences are language, logic, morals, and others. Definition of the meaning of the words of the law, and the modification of this meaning by the use of other intermediate words, and the application of logic, is the business of a jurist, and therefore, the unanimous decision of all jurists, from ancient times to the present day, to the effect that the mental effort of one man cannot be measured by another man, must be taken as conclusive that such is a fact. The effect of this decision upon all engagements for mental labor is that such contracts must necessarily be based on the honor and conscience of the person undertaking to perform that labor. When the mental work is to be, or must be, accompanied by certain bodily movement, there may be a means of vaguely determining that the work was not performed, but there is no means of determining that it was performed except by results, and then only in the judgment of the person judging, and he may not be qualified to determine. When the result to be achieved takes a material form, the contract is one for material work and can be specified, but where the result is an opinion, the fee or reward is earned when the opinion is given, no matter how absurd the opinion may seem to the person who pays for it.

The practice of engineering requires the performance of skilled mechanical labor, such as draughting, measuring, surveying, etc., which is capable of specification, and mental work, such as designing, the supervision of construction, etc., the full extent of which it is not possible to specify, except in general terms. Although the mechanical work can be done by those unable to do a large part of the mental work, and frequently is done by such, the best results are obtained by having this work done by those capable of checking the designing computation of each item as the design is drawn, and of making all the computations required in surveying, as the mental labor which should accompany this class of work cannot be closely defined, and the observations recorded may be so meagre and incomplete as to nullify the value of skilled mechanical work. Continuously applied mental labor should accompany all the mechanical acts of an engineer, and the assistance they can secure from mechanics is so little that it may be disregarded.

Engineers are therefore bound, when receiving compensation for mental work, to do that work as if the resulting benefit were to be their own, and this is the lower aspect of their duty. To remain at any level of morals, it is necessary to constantly strive to attain a higher level, and it may be said that, to do his full duty

to his employer, an engineer should strive to do more than he would do for his own benefit.

Employment is frequently given by people who are not familiar with the nature of the work they wish to have done and who expect either too much or too little from the engineer employed. The service that should be given to such an employer should be equal to that given to a skilled engineer by his assistant. An engineering expert employed to supervise the steel construction of a great bridge does not work a certain number of hours per day and then throw the subject from his mind until the next day, as laborers throw down their tools. He fills his mind with the subject assigned him, thoroughly studies the general design, to enable him to better fulfil the task he has undertaken, seeks frequent consultations with his chief, and gives long and patient consultation to his own assistants. If he discovers a discrepancy, he at once shows it to his chief to have the matter corrected, not hiding the error to mortify him by one oversight in a great and skillful design. Perfection in an intricate design can be secured only by conscientious checking of all calculations and revision of all connecting details, and the assistant knows that *that* is part of the work assigned for him to do, and whilst he diligently seeks for errors, it is not as a critic, but to help the designer, who well knows that an error may have passed into his calculations. The assistant in charge of a specialty in a great work is practically chief of that department, but loyally works in accord with the designer of the whole work, from whom he has accepted employment, and he charges his mind with the full responsibility of the work he has undertaken, making it the engrossing study of every waking hour until the work is completed, as much so as the designer, and as greatly rejoices in final success. This conscientious, loyal, and total engrossment with the work, loving it as the chosen life-work, and striving to make it perfect, is recognized as "professional spirit."

Ruskin states somewhere, in substance, that "a true workman is one who works for love of the work and a desire to attain the greatest possible perfection in its execution, regardless of reward or the approbation of others," but the ability to work in this way is an impossibility to all who are without means of living, apart from the earnings of work. To bring this definition of true workmanship or professional spirit within the conditions of life, it is necessary to so modify this statement as to require only that a workman should have the enthusiasm to do this, if he had the means of supplying his physical needs and moral obligations when working.

With the ideal thus modified, a professional man may be defined as one who regards the work he is engaged in to be of greater importance than the financial reward he receives for doing it, and, if the reward is sufficient to supply his physical needs, together with the moral claims upon him, the mental satisfaction of having striven for success, whether achieved or not, is in itself sufficient reward. It does not require much reflection to perceive that this ideal professional man is one who strives towards a moral perfection which is practically unattainable, and this shows that true professional spirit is a striving to attain moral perfection, and the efforts made will tend to stimulate moral development.

The remuneration to be received for service is a matter to be considered once only, when the employment is offered, and before acceptance. When the employment is accepted it can only be surrendered, by one actuated by true professional spirit, at such a time and under such conditions as will ensure the employer from loss.

From the foregoing the following deduction is made, viz: that the members of a profession *profess* to be actuated by higher moral obligations than are commonly recognized in the engagements of life. The purist may say that all men should be actuated by moral principle, but the professions say that, although this is true, the fact is that popular morals are lax, but we profess to be so actuated, and our claim should be recognized if we live consistently with our profession.

A NEW TESTING MACHINE AND THE CROSS-BREAKING TEST OF VITRIFIED PAVING BRICK.

By F. F. Harrington, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 6, 1897.*]

On July 17 of last year a paper by the writer, entitled "Experiments on Vitrified Paving Brick," was read before this club, and published in the August number of the Journal of the Association of Engineering Societies. In that paper were proposed for adoption specific methods of making the rattler and absorption tests in the St. Louis Testing Laboratory. In the article referred to it was mentioned, also, that a new testing machine for the cross-breaking test of vitrified paving brick, with a capacity of 25,000 pounds, had been designed by Mr. M. L. Holman. The object of the present paper is to describe this testing machine and to give the results of an investigation of the cross-breaking test of paving brick. The experiments were made by Mr. S. M. Woodward, now Professor of Physics in the University of Arizona, and the author, under the direction of Mr. Holman.

Fig. 1 is a view of the machine with a brick in position to be broken, and Fig. 2 shows the general design. A wrought-iron hood 16" x 16" x 14" high, not shown in the figures, rests on the bed-plate and confines the broken brick. In the front of the hood is an opening 11" wide and 7" deep from the top, so that the brick can be properly adjusted for the test, and on the side is a door, from which the broken specimen is removed.

The machine consists of a vertical cast-iron cylinder, 17.99" ± .01" in diameter and $14\frac{1}{2}$" high, inside dimensions, containing a plunger 8" high, connected to a steel cross-head above by means of a single steel rod 2.05" ± .01" diameter. This rod passes through a self-adjusting metal stuffing box bolted to the cylinder, and also through a fixed babitted bearing placed in the top of a cast-iron cylindrical collar $16\frac{1}{2}$" high, also bolted to the cylinder. To the cross-head are attached two steel links $8\frac{1}{2}$" center to center, separated $4\frac{1}{2}$" from each other, and containing a rectangular steel bar with four knife edges, two of which, diagonally opposite, are sharp and the other two well rounded. The knife edges for the support of the brick are well rounded, both longitudinally and

*Manuscript received January, 1897.—Secretary, Ass'n of Eng. Socs.

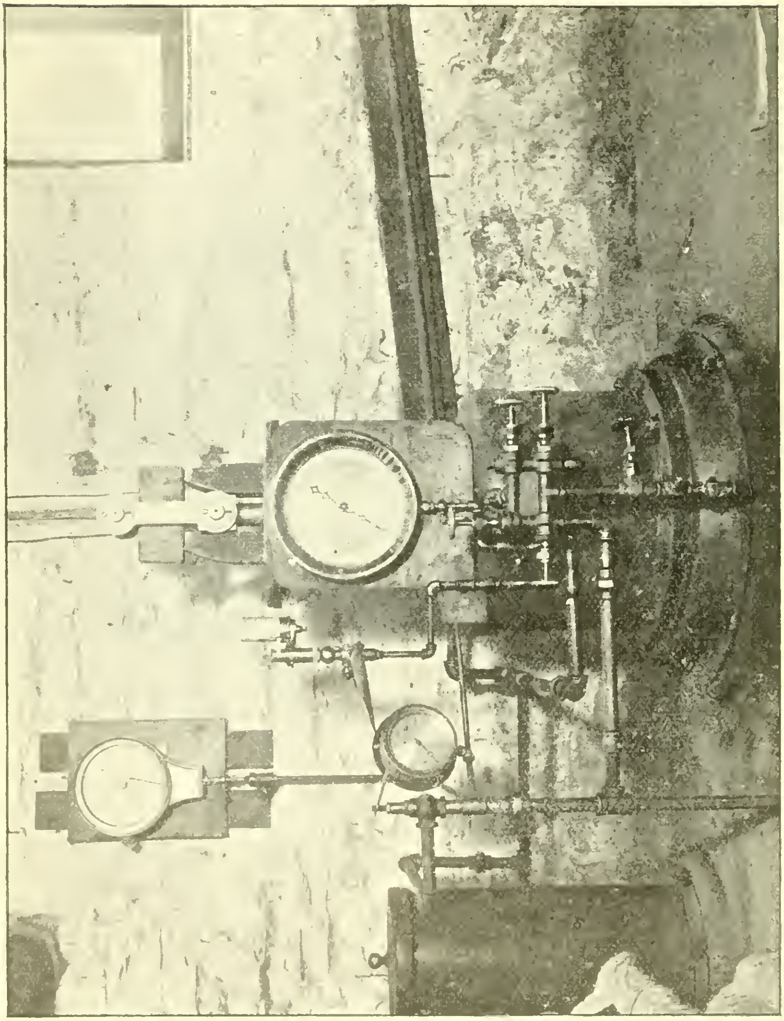


Fig. 1.—Testing Machine for Paving Brick in Cross Breaking.

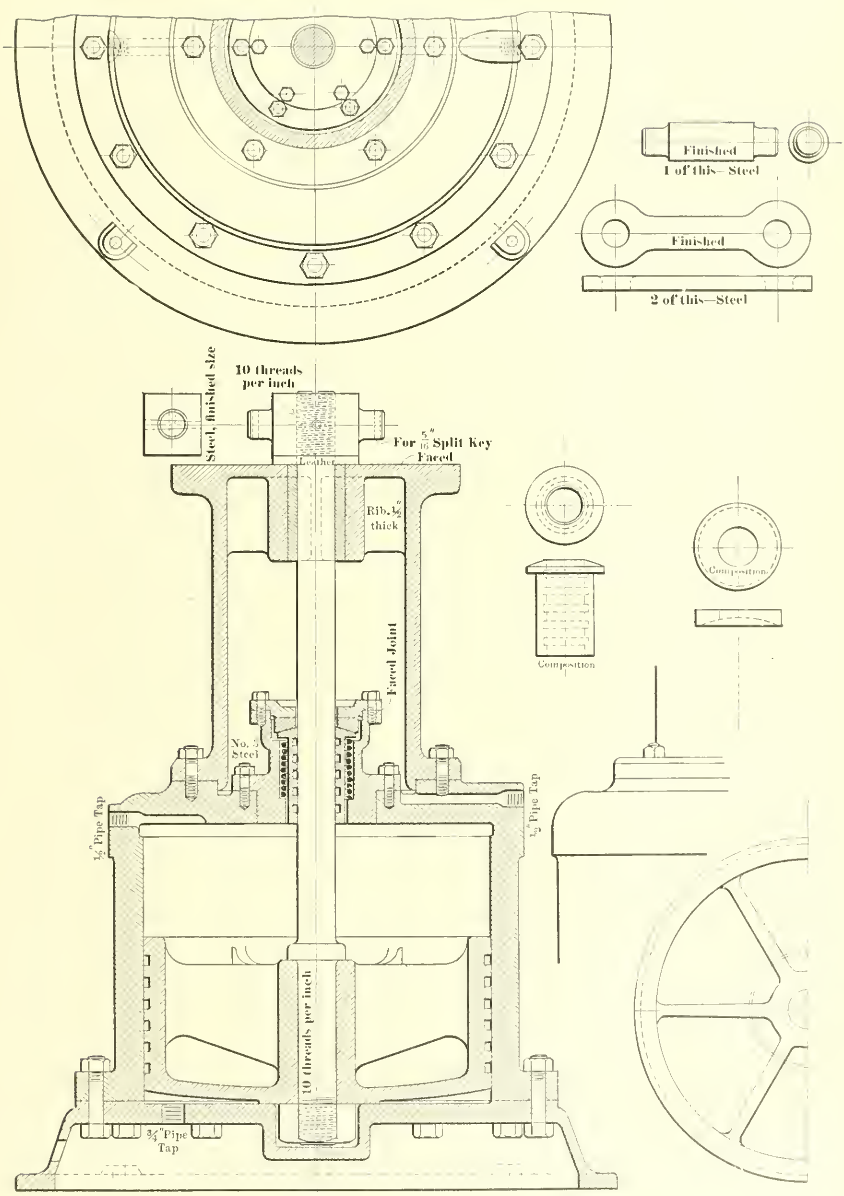


FIG. 2.—HYDRAULIC TESTING MACHINE. CAPACITY 25,000 POUNDS. SCALE 1-10.

transversely, and are so bolted together that a span of six inches is secured.

The novel feature of the machine is the method adopted for reducing the friction to the smallest possible amount. For this purpose the plunger is made to fit loosely in the cylinder and the piston-rod in the self-adjusting stuffing box. On the outer surface of the plunger are turned six rectangular grooves $\frac{1}{2}''$ wide and 5-16″ deep, and in the packing about the plunger rod in the stuffing box are five rectangular grooves $\frac{3}{8}''$ wide and 3-16″ deep. The oil, therefore, leaks around the plunger and through the stuffing box when pressure is applied, This oil fills the grooves and keeps the bearings in a thoroughly lubricated condition. The leakage of oil past the plunger and through the stuffing box is forced through pipes to the oil tank.

The oil is supplied by a Gould triplex pump from a constant-speed electric motor. Each plunger of the pump is $1\frac{1}{4}''$ diameter and 2″ stroke. The speed is about 40 revolutions, and hence pumps about $1\frac{1}{4}$ gallons per minute. The air chamber on the pump has a capacity of about half a gallon. About 20 gallons are required to fill the testing machine, connections, and oil tank to a point above the return pipe. The oil used has a specific gravity of .89 at 80° F.

To the pipe supplying the oil to the cylinder are attached a small pressure gauge and a safety valve. To the cylinder are connected a pressure gauge with a dial $7\frac{1}{2}''$ in diameter, graduated from 0 to 100 pounds, a steam indicator attachment, and a recording pressure gauge indicating pressures from 0 to 100 pounds. Check valves are placed in the pipes leading to the gauges.

The movement of the plunger is controlled by a system of four conical valves, shown in Fig. 1 and in section in Fig. 3. The following description of the method of breaking a brick will explain the operation of the machine by these valves. Having started the pump, to raise the plunger, valves A and C are closed and B and D opened. When the cross-head is raised sufficiently a brick is adjusted on edge on the rounded knife edges. The plunger is then lowered by opening valves A and C until the middle knife edge comes in contact with the top of brick, care having been taken to make the planes containing the center lines of the links and the opposite knife edges of the rectangular bar coincident and vertical. It will thus be seen that the plunger rod cannot be subjected to cross strains, for if the above conditions are not fulfilled the rectangular bar will revolve in the links, making a new adjustment necessary.

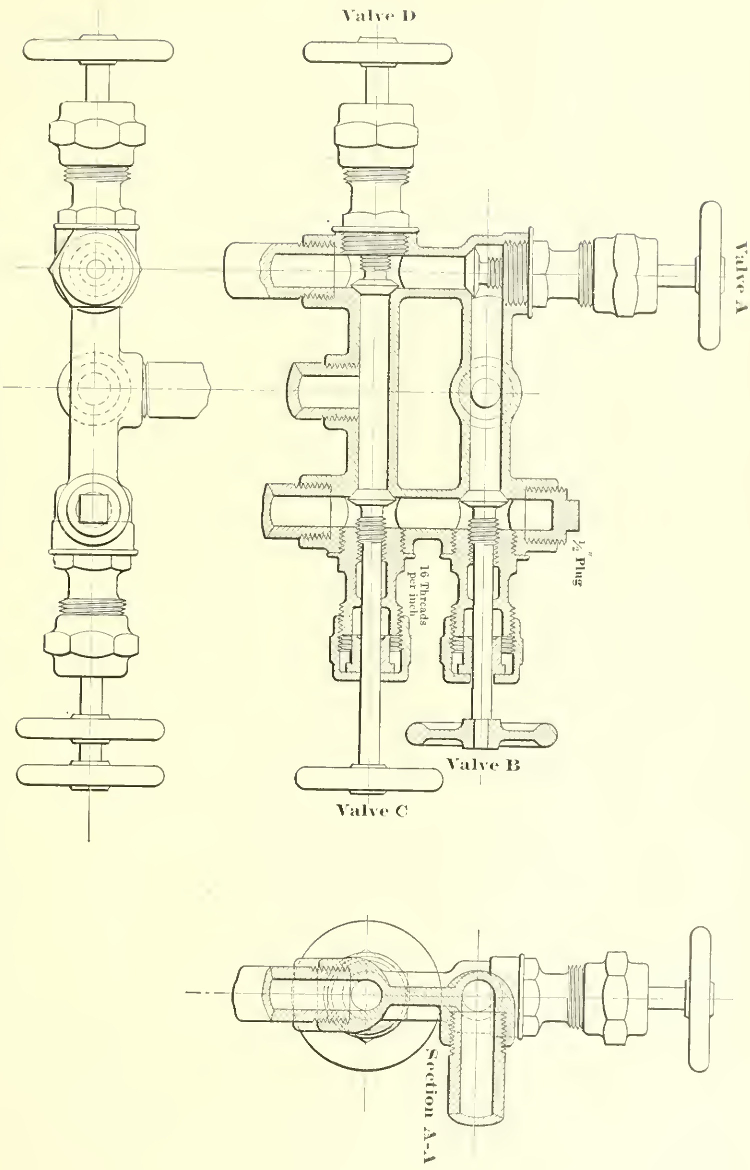


FIG. 3.—REGULATING DEVICE FOR TESTING MACHINE. SCALE 1-3.

Valve D is then closed and A partially closed until the pressure on gauge in supply pipe is about 20 pounds. This throttling of A is done in order to keep the pressure in the supply pipe a definite constant amount greater than that in the cylinder, so that, when a test specimen breaks, the pump is largely saved from shock and the air chamber is prevented from emptying itself, thus saving in the time required to pump up to a new pressure. Valve B is now gradually closed, raising the pressure in the cylinder uniformly by the throttling of the oil, until the brick is broken. The corresponding pressure is recorded. When two or more bricks are to be broken, valves B and D are quickly opened and A and C closed, and by the time the broken specimen is removed the cross-head is raised enough to adjust the second specimen, and the foregoing cycle of operations is repeated for each test.

LEAKAGE.

A series of experiments was made to determine the relation between the leakage around the plunger and the pressure in the cylinder, to serve as a guide in the selection of a pump for a new hydraulic machine of 1,500,000 capacity, for crushing materials of construction, which was designed by Mr. Holman upon the same general principle, but in which the pressure in the cylinder is very high.

Let H = distance from bottom face of cross head to top of bed-plate. Then the limiting values of H, when the plunger is at the bottom and at the top of its stroke, are H = 13-16″ and 6 7-16″.

The diameter of the plunger is practically uniform throughout its length, but the diameter of the cylinder increases somewhat from the bottom to the top. The leakage was therefore determined for values of H of 1″, 2″, 3″, 4″, 5″, and 6″. These respective heights were obtained by two blocks of cast iron 5″ x 3″ x 1″ and two 6″ x 4″ x 2″, which were placed between the cross-head and bed-plate to block the machine, the links having been removed. The return pipes from the bottom of the cylinder and above the cylinder were closed by gate valves, and pet cocks in the pipes opened to permit the escape of the oil. At each height of the plunger the leakage was obtained for pressures in the cylinder of 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 pounds. At each pressure the oil was allowed to flow until the stream was steady, after which it was collected in a gallon measure for exactly one minute, care being taken to keep the pressure constant, and the difference in weight between the can before and after the

experiment gave the weight of the oil escaping, which was found to the nearest gram. Fig. 4 shows the results of these tests, the flow Q in cubic inches per minute and the pressure P in pounds per square inch being plotted. The leakage is nearly directly proportional to the pressure. The curves can be closely fitted by equations of the form $Q = KP^n$. Each curve is marked with its corresponding equation, and points which exactly satisfy the equation are also shown.

Experiments on the leakage through the stuffing box were made in a similar manner, except that in each case five minutes were allowed in order to permit the flow to become steady, and the leakage then obtained for five minutes was weighed. The results are given in Table I.

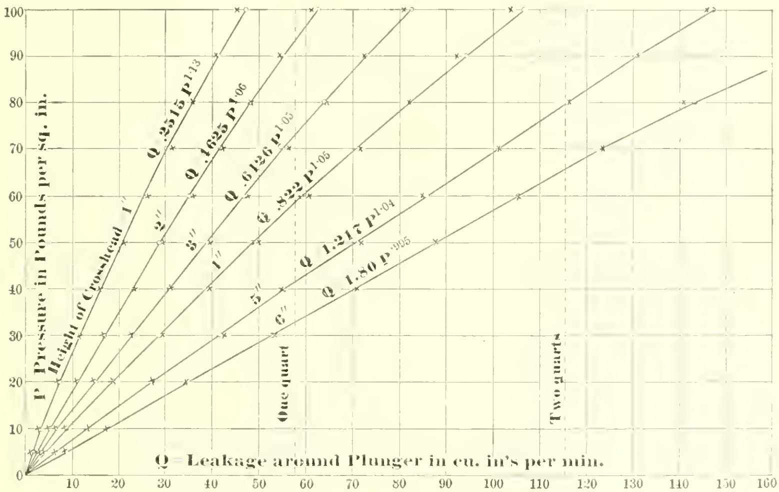


FIG. 4.—LEAKAGE CURVES.

TABLE I.

Pressure—Pounds per sq. in.	Leakage through Stuffing Box-Grams per five minutes. Decreasing Pressure.	Increasing Pressure.
100	40	36
90	35	34
80	31	31
70	27	28
60	24	25
50	21	21
40	16	18
30	15	14
20	11	8
10	7	6

CALIBRATION AND FRICTION.

During the progress of the experiments it was necessary to test frequently the large pressure gauge. This was done by means of a Crosby dead-weight gauge-tester belonging to the Water Department. It was found that the spring in the gauge became more unyielding, so that the corresponding readings were slightly lower as the gauge was longer in service, and the face of the gauge was graduated accordingly after each test. The maximum deviation from the original graduations was 1.7 pounds at 100 pounds pressure, which decreased quite regularly to 0.6 at 5 pounds pressure.

The graduated cards accompanying the recording gauge were found inaccurate, so it was calibrated by means of the pressure gauge. A plain sheet is therefore now used on the recording gauge, and the breaking load read by a scale prepared for the purpose, an initial circle representing 5 pounds pressure being first drawn on the sheet.

Fig. 5 shows the method used in calibrating the machine and determining its friction. A steel I-beam 4″ deep, 2 13-16″ wide, and 70″ long was passed between the links and supported at one end on a standard resting on the bed-plate, while the other end was suspended in a stirrup attached to the main knife edge of a 1,000-pound Riehle cement testing machine. The knife edges and their bearing surfaces were of hardened steel, and arranged in a straight line on the top of the beam. The cement machine was first balanced with the beam removed. The beam was then replaced and the portion of its weight carried by the cement machine recorded. The plunger of the cross-breaking machine was then lowered until its weight was carried by the beam, and a second reading on the cement machine recorded. For the calibration the sharp knife edge of the rectangular bar was used, and the bearing plate chalked so that an accurate measurement of the leverage could be obtained. Pressure was then applied and readings taken on the gauge while it was changing at a uniform rate for each 100 pounds increase on the cement machine forward and backward. For any given reading on the cement machine, the difference between the readings on the pressure gauge when the load was increasing and decreasing was taken to represent twice the sliding friction of the plunger. Table II shows the results of two sets of experiments made on July 27 and August 15.

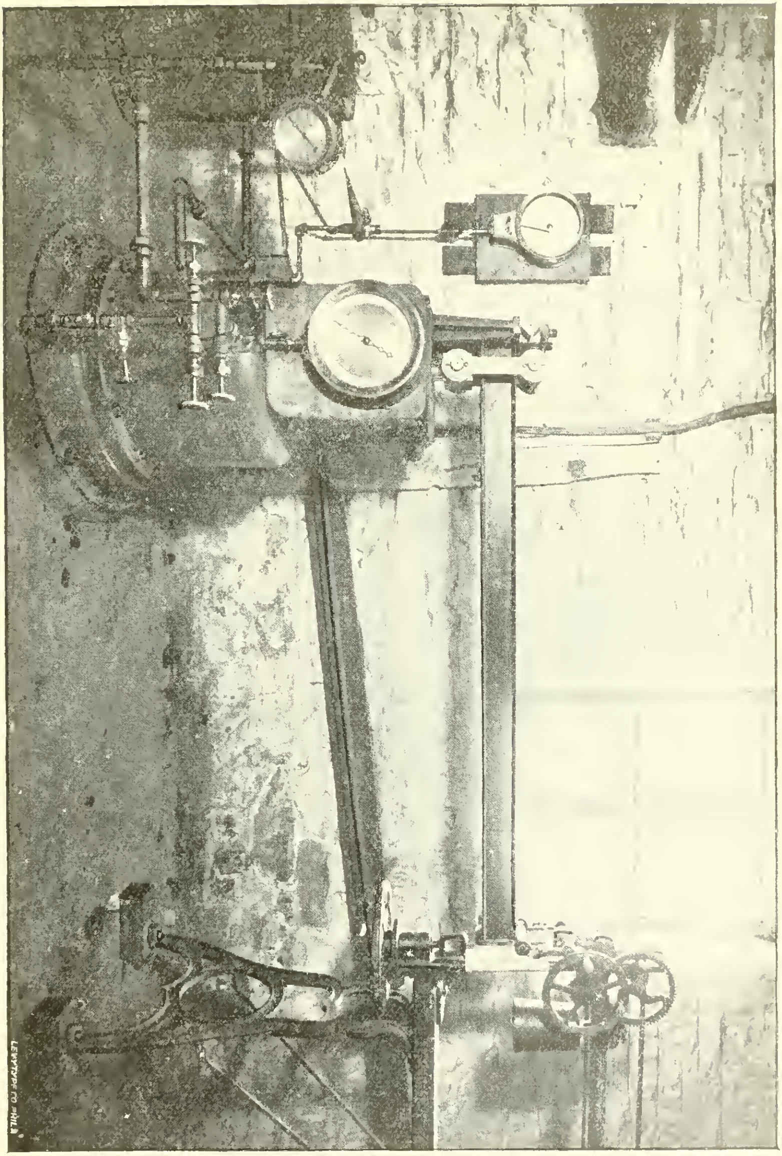


Fig. 5.—Calibration of Testing Machine.

TABLE II.

FIRST SET—JULY 27.

Cement Machine Readings, lbs.	Gauge Readings. Increasing Pressure, lbs.	Decreasing Pressure, lbs.	Average Pressure, lbs.	Force Friction, lbs.
32				
46				
146	8.3	8.0	8.15	0.3
246	16.3	16.0	16.25	0.5
346	24.4	24.0	24.20	0.4
446	32.4	32.1	32.25	0.3
546	40.6	40.1	40.35	0.5
646	48.7	48.0	48.35	0.7
746	56.9	56.2	56.55	0.7
846	54.9	64.1	64.50	0.8
946	72.9	72.1	72.50	0.8

SECOND SET—AUGUST 15.

33				
46				
146	8.3	8.0	8.15	0.3
246	16.5	16.0	16.25	0.5
346	24.4	24.0	24.20	0.4
446	32.3	32.0	32.15	0.3
546	40.7	40.0	40.35	0.7
646	48.9	48.1	48.50	0.8
746	57.0	56.0	56.50	1.0
846	65.0	64.0	64.50	1.0
946	73.0	72.1	72.55	0.9

The average gauge pressures and their corresponding readings on the cement machine in the above experiments fall, when plotted, very nearly on a straight line, showing that the load is directly proportional to the pressure.

To find the pressure to be allowed for the weight of the plunger, we have, from first set,

$$\frac{46-32}{900} \times 72.5 = 1.13.$$

and from second set,

$$\frac{46-33}{900} \times 72.55 = 1.05.$$

The arms for the first set were 3.30″ and 66.55″.

The area of plunger is therefore

$$\frac{900}{72.5} \times \frac{66.55}{3.30} = 250.4.$$

The arms for the second set were 3.28″ and 66.55″, and the area of plunger

$$\frac{900}{72.55} \times \frac{66.55}{3.28} = 251.7.$$

The area of the top of plunger from measurement is

$$(17.99^2 - 2.05^2)\ .7854 = 250.9 \text{ sq. in.}$$

The weight of the plunger, rod, crosshead, links and knife edge in air is 295 lbs.

Fig. 6 shows the final calibration line for the testing machine which is straight and calculated from the following data:

Area of plunger—251 square inches.

Gauge pressure allowed for weight of plunger and connections, 1.1 pounds.

Friction, nothing at zero pressure, and 0.5 pounds at 100 pounds pressure.

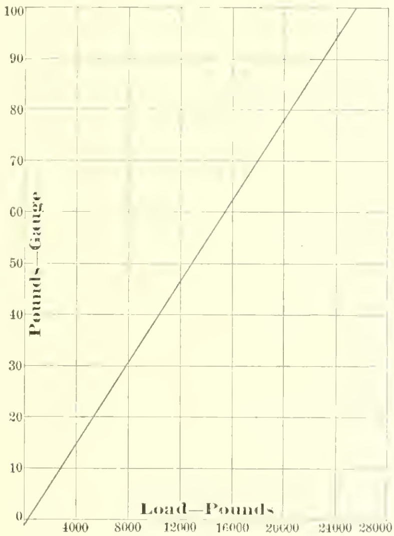


Fig. 6.—Calibration Line.

The chief features of the Testing Machine, briefly, are:

1. The friction is reduced to a very small amount, by causing the oil to leak around the plunger and rod, thus maintaining oil bearings, and eliminating packing.

2. It is simple in construction, having very few moving parts.

3. The load on the specimen is under perfect control at all times, and can be applied uniformly, released instantly, or held constant for any length of time.

4. The results obtained are accurate to within one per cent.

5. Specimens can be broken for commercial purposes rapidly, without physical labor and by one operator.

6. The load on the specimen is indicated by a pressure gauge and a record of the tests made is also kept on an autographic recording gauge.

THE CROSS-BREAKING TEST.

The cross-breaking test of paving brick is important for the following reasons:

1. It furnishes a means of comparing the toughness of various kinds of clay paving material.

2. For any particular kind of brick, it shows whether the material has been properly treated in the various stages of its manufacture.

3. It indicates the resistance of the material in cross-breaking when laid in the pavement on an unyielding and uneven surface.

4. The cross section being exposed, the interior structure may be examined.

The method of making the test consists in supporting the brick on edge upon rounded knife edges with a span of six inches, applying the load uniformly to the middle of top face until broken and computing the modulus of rupture from the ordinary cross-breaking formula,

$$f = \frac{3\,w\,l}{2\,b\,d^2}$$

in which

f=modulus of rupture.

w=total breaking load.

l=span in inches.

b=breadth of brick in inches.

d=depth of brick in inches.

In order to facilitate the calculation of the modulus of rupture, a slide rule has been prepared, which is graduated as follows: On the limb are two scales, the upper representing the width of the brick in inches, the limits being 1.5 and 6 inches, graduated to fiftieths of an inch, and the lower being the modulus of rupture from 500 to 7,000 pounds per square inch, graduated from 500 to 3,000 in 10 pound; from 3,000 to 5,000 into 20 pound, and from 5,000 to 7,000 into 50 pound divisions. On one side of the slide are two scales, the upper being the depth of the brick having limits 1.3 to 5 inches, graduated to 1-100 inch, and the lower being the total load taken from the calibration line of the testing machine shown in figure 6, graduated from 6 to 80 pounds on the gauge

into 1-5 pound, and from 80 to 100 into ½ pound divisions. On the opposite side of the slide are two scales, the upper being the depth, as on the first side, and the lower being the total breaking load in pounds avoirdupois from 2,000 to 27,000, graduated from 2,000 to 10,000 into 50 pound; from 10,000 to 20,000 into 100 pound, and from 20,000 to 27,000 into 200 pound intervals.

In using the rule, the width and depth of the brick having been measured to the nearest hundredth of an inch, the depth on the slide is set opposite the width on the limb. Then opposite the breaking load on the slide, the modulus of rupture is read off on the limb. The modulus of rupture, in pounds per square inch, can thus readily be found to the nearest 10 pounds in the case of a brick tested edgewise or flatwise, broken either on the hydraulic or on some universal testing machine.

In order to avoid the necessity of grinding the surfaces to parallel planes for the cross-breaking test, and at the same time to reduce the twisting strains due to the irregularity of those surfaces to a minimum, the lower knife edges were slightly rounded longitudinally as well as transversely, while the upper knife edge was made straight longitudinally but rounded transversely. This results in a concentration of stress upon two small areas of the brick in contact with the lower knife edges. In the early experiments these knife edges were sharp, and the specimen broke frequently in a well-defined curved surface, beginning at one of the lower knife edges, bending convex upward and terminating near the upper knife edge. This led to an investigation of the theory of the lines of stress in a brick in cross-breaking, which, although based on various assumptions, accounted for the character of the rupture. Consider a brick supported on edge on knife edges 6″ apart, with a concentrated load in the middle. The total shear is then constant between the support and the load, but for any vertical section it varies as the ordinates of a parabola having its vertex on the neutral axis, where the shear is a maximum, and diminishing to zero at the upper and lower surfaces. The fibre stress due to the bending moment varies uniformly on a horizontal section between the vertical section through the middle where it is a maximum, and the vertical sections through the supports where it is zero; it also varies uniformly from the neutral axis where it is zero, to the lower surface where it is a maximum in tension, and from the neutral axis to the upper surface, where it is a maximum in compression. A combination of these two stresses at any point by the method of Rankine's theory of the "Eclipse of Stress" gives the resultant principal tensile stress in direction and amount.

Figure 7 represents a brick 8″ long, 4″ deep and 1″ wide, on supports 6″ apart and loaded with one pound in the middle. The principal tensile stresses were computed for points from the center

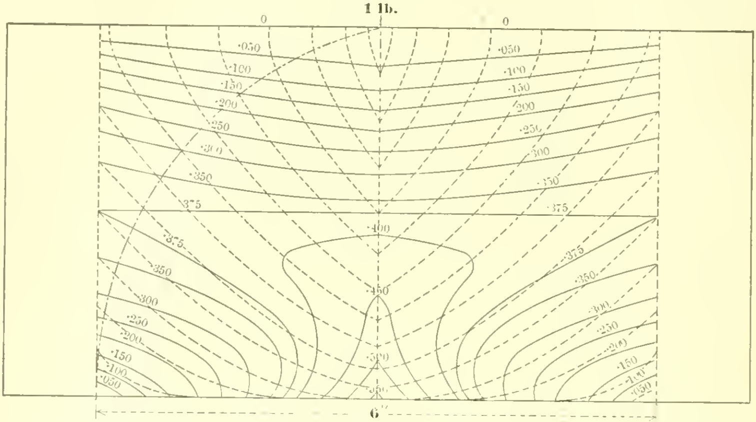


FIG. 7.—PRINCIPAL TENSILE STRESS LINES, DIRECTIONS AND LINE OF RUPTURE.

to one support (the two halves being symmetrical) varying from each other by distances of ½″ vertically and horizontally. Lines were then drawn, connecting points of equal stress*, which are

*The general formula for the principal tensile stress lines is:—

$$k^2 - pxy = y_1^4 p - p_2 y^2 + p_1 y^4$$

$$\text{Where } p = \frac{6k}{h^3},\ p_1 = \frac{36}{h^6},\ p_2 = \frac{72 y_1^2}{h^6}$$

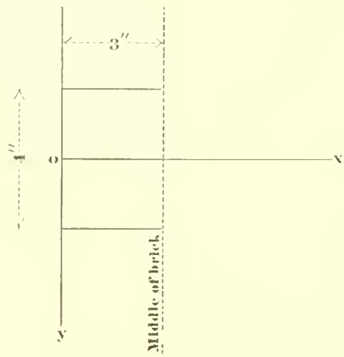
k = coefficient marked on stress line.

$$y_1 = \tfrac{1}{2} \text{ depth of brick} = \frac{h}{2}$$

$$\frac{dy}{dx} = \frac{py}{2p_2 y - px - 4p_1 y^3}$$

If $\frac{dy}{dx} = 0$, $y = 0$, or the tangent is horizontal only at the neutral axis.

If $k = .5$, $x = 3$, $y = 1.62$, $h = 4$, $y_1 = 2$, then $p = \frac{3}{64}$, $p_1 = \frac{9}{1024}$, $p_2 = \frac{9}{128}$, and $\frac{dy}{dx} = -1.227$, or the tangent to the stress line, $k = .5$, at the middle of brick is about 51°.



shown by the full lines, the stresses being marked upon them, and the directions of the stresses are shown by the dotted lines. For a brick of different width and loading, the magnitude of the stress is found by multiplying the figures on the diagram by the ratio of the total load to the width in inches.

Theoretically the external forces are supposed to act uniformly over the whole vertical cross section of the brick, but practically these forces are concentrated over the small area in contact with the knife edges, so that the lines shown in Fig. 8 will be greatly distorted. When a specimen breaks at the knife edge the rupture is started by the intense compressive stress at that point after which it tends to follow at right angles to the directions of the lines of principal tensile stress as shown by the broken line on the diagram.

The lower knife edges were then rounded transversely to a larger radius and this difficulty was practically overcome. Further experiments with bricks of inferior quality, however, showed that occasionally a specimen broke in the above manner, and to counteract this two remedies were applied with success, the first being to place small steel plates between the lower supports and the brick and the second to break the specimen flatwise, thus spreading and reducing the concentrated forces.

In the following tables, III to VII, inclusive, are given the results of some cross-breaking tests on paving brick of different manufacture, each being numbered and described in table VIII. The figures represent the moduli of rupture in pounds per square inch.

Table III. Ten bricks were broken with load applied at the rate of 2,500 pounds per second, after which ten of the same kind were broken in a similar manner at the rate of 250 pounds per second. The results are practically the same.

Table IV. Ten bricks were broken edgewise and flatwise on the Hydraulic Machine, and ten of the same kind were broken edgewise and flatwise on a Riehle 20,000 pound Testing Machine at Washington University, with practically the same results.

Tables IV., V. and VI. Samples of different manufacture were broken edgewise and flatwise. Theoretically for brick of any one make the results should be equal, but the method of manufacture and repressing tend to vary them. The higher averages of the same kind of brick when broken flatwise than when broken edgewise may be accounted for by the repressing process. From the tests given in the tables and others not recorded it is believed that a comparison of tests edgewise and flatwise on carefully-chosen

samples of the same kind of brick is an excellent means of ascertaining the homogeneity of the material. The tables also show that in a series of tests the individual results are very variable, and thus to secure a uniform paving material, the average value and the range of variation of individual results from the average should be specified.

Table VII. These results show the weakening effect of a flaw in the specimen. An examination of the fractured surface showed that Nos. 8, 9 and 10 of paving brick No. 5 and Nos. 2 and 7 of No. 6 were more or less air-checked, causing a great reduction in their strength. Cross-breaking discloses such defects better than any other test applied to paving brick.

From the preceding experiments the following methods for making the cross-breaking test is proposed. Support the brick on edge on hardened steel knife edges well rounded transversely and slightly rounded longitudinally, bolted to secure a span of six inches, and apply the load in the middle of the top through a third knife edge rounded transversely, but straight longitudinally. Samples for test should be free from all visible irregularities and defects with practically parallel upper and lower faces, and not less than ten should be broken.

TABLE III.

FAST AND SLOW BREAKING—PAVING BRICK NO. I.

	Fast.	Slow.
1	3020	3270
2	2900	2700
3	2670	2760
4	3520	3070
5	3020	2590
6	2790	2330
7	2730	3300
8	3360	2360
9	2500	2330
10	2340	2590
Average	2885	2730

TABLE IV.

BROKEN EDGEWISE AND FLATWISE—PAVING BRICK NO. I.

	Hydraulic Machine.		Riehle Machine.	
	Edgewise.	Flatwise.	Edgewise.	Flatwise.
1	2730	2050	2700	3600
2	2670	3420	3380	3170
3	2760	3550	2950	2310
4	2310	2370	1830	3240
5	2450	2050	2250	2230
6	2710	3320	2860	2270
7	3330	3140	2590	2590
8	2870	3370	2840	3130
9	3440	2510	3650	2920
10	2640	3420	2540	2450
Average	2791	2920	2759	2791

TABLE V.

BROKEN EDGEWISE AND FLATWISE—PAVING BRICK NO. 2.

Size.	8 x 3¾ x 3½		8 x 3¾ x 3		8 x 3¾ x 2½	
	Edgewise.	Flatwise.	Edgewise.	Flatwise.	Edgewise.	Flatwise.
1	2720	2890	2480	3000	1930	2920
2	2820	3240	3070	3030	2140	1850
3	2540	2560	3080	3380	2910	3110
4	2080	2600	2990	3360	3170	3400
5	2580	2210	2350	3890	2070	3020
6	2260	2850	2410	3400	2260	1950
7	2580	2480	2580	3290	2580	2820
8	2080	2990	2810	2890	1880	2920
9	2450	2140	3500	3000	3100	2530
10	2720	2730	2820	3780	3620	3700
Average	2483	2669	2809	3302	2566	2822

TABLE VI.

BROKEN EDGEWISE AND FLATWISE—PAVING BRICK NOS. 3 AND 4.

	Number 3.		Number 4.	
	Edgewise.	Flatwise.	Edgewise.	Flatwise.
1	3500	2780	2970	2950
2	2840	3480	2120	3030
3	2780	3300	2870	2830
4	3260	3250	2000	2940
5	3260	2820	2330	2710
6	2840	3480	2260	2680
7	3570	3010	2960	2790
8	3500	3530	2940	3020
9	2750	2970	2230	3160
10	2660	3340	2140	2920
Average	3096	3196	2482	2903

TABLE VII.

EFFECT OF FLAWS—PAVING BRICK NOS. 5 AND 6.

	Number 5. Edgewise.	Number 6. Edgewise.
1	1950	3230
2	3130	930*
3	2140	2560
4	2340	2750
5	2230	2520
6	2010	2560
7	3320	1330*
8	1100*	3260
9	1550*	3300
10	1240*	2260

* Fracture shows air check.

TABLE VIII.

DESCRIPTION OF PAVING BRICK TESTED.

No.	Material.	Dimensions.	Remarks.
1.	Shale	$8\frac{1}{4} \times 4 \times 2\frac{1}{2}$	Repressed.
2.	Shale	$8 \times 3\frac{3}{4} \times 3\frac{1}{2}$ $8 \times 3\frac{3}{4} \times 3$ $8 \times 3\frac{3}{4} \times 2\frac{1}{2}$	Repressed.
3.	Shale	$8\frac{1}{4} \times 4 \times 2\frac{1}{2}$	Repressed.
4.	Shale	$8 \times 3\frac{1}{4} \times 2\frac{1}{2}$	Repressed.
5.	Shale and fireclay	$9 \times 4 \times 3$	Repressed.
6.	Shale and fireclay	$9 \times 4 \times 3$	Repressed.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis;

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING, HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a chairman and secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a

synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the chairman for countersignature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

SEC. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC 3. Any society may, at the pleasure of the Board, be excluded from this Association, for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following societies have since certified their acceptance of the Articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

The Engineers' Club of Kansas City disbanded at the close of 1896.

Annual Report of the Chairman of the Board of Managers.

BOSTON, December 31, 1896.

To the members of the Board of Managers of the Association of Engineering Societies:—

GENTLEMEN:—In transmitting to you the report of the Secretary of the Association, I desire to avail myself of the opportunity to express my appreciation of the honor which you have conferred upon me in electing me chairman of the board. The business of the Association had been conducted so ably by the two gentlemen who had preceded me that I assumed the position with some hesitancy, but as you had at the same time re-elected our efficient Secretary, Mr. Trautwine, I felt that in his hands the business

of the board would be skillfully managed and the end of the year would find the Association in good condition. A careful examination of his very full report of the work of the year shows that this faith was not misplaced, and I desire to express my sincere appreciation of his valuable services and his untiring zeal in the interest of the Association.

The past year has been a prosperous one for the Association, although marked by no important transaction. The dissolution of the Engineers' Club of Kansas City and its practical withdrawal from membership at near the close of the year is the only event which calls for special mention.

All papers which have been forwarded for publication have appeared promptly in the JOURNAL, and in a manner entirely satisfactory to its readers. The reduction of nearly 25 per cent. in the amount of matter presented during the year by the societies now in the Association is an occurrence to which the attention of the members of the several societies should be called, and the fact should be impressed upon the committees having charge of the preparation of papers that the present financial condition of the Association is such that papers can be published in the JOURNAL in as satisfactory a manner and as profusely illustrated as in any publication now reaching the profession.

The question of resuming the publication of the index to current engineering literature in the JOURNAL is one that has been brought to the attention of the Chairman, and he has given it careful consideration and has consulted with members of the various societies. The cost of preparing and printing these index notes is so large that the matter should be left in the hands of the *Engineering Magazine*, if such arrangements can be made with that journal as will ensure to the profession the publication of an annual index summary, with a re-compilation, say every five years. If this cannot, under the present arrangement, be secured, the question should be carefully considered by the board and the publication resumed by the Association in a manner that will be satisfactory to the profession.

Respectfully submitted,

S. E. TINKHAM, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, DECEMBER 31, 1896.

Mr. S. E. Tinkham, Chairman,

65 CITY HALL, BOSTON, MASS.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1896, and of the condition of the Association at the present time.

The abandonment of the publication of the Association's extremely valuable "Index to Engineering Literature" has had, for its immediate result, a notable improvement in the financial standing of the Association, the excess of assets over liabilities having increased from $223.93 at the close of 1895, to $1,244.94 at the close of 1896.

It may well be questioned, however, whether this gain is altogether a matter for congratulation. The abandonment of the index necessarily reduces the value of the JOURNAL, not only to subscribers and other readers, but also to advertisers, and it may thus result in some loss which will, to some extent at least, offset the gain now shown by the books.

Nothing worthy of the name of an index to current literature has been given to the profession as a compensation for the loss of the index heretofore published by the Association in its Journal, and the engineering literature of 1896 is without an index.

By reason of the withdrawal of the Western Society of Engineers at the close of 1895, and the disbanding of the Engineers' Club of Kansas City during 1896, the Association, at this date, embraces but nine societies, with a total membership of 1,106, as against eleven, with a total of 1,477, at this time last year, but the Detroit Engineering Society, with a mailing list of 87 names, has voted to join the Association and will undoubtedly become a member early in 1897.

The list of subscribers shows a gratifying increase during 1896.

It is much to be hoped that the societies will take early and efficient action in the matter of securing from their members advertisements for the JOURNAL. The present rule of the Association is to allow the societies 50 per cent. of the cost of advertisements.

Apart from the business advantage of the advertisement, the societies can thus secure what amounts practically to a material reduction in their assessments, and those of their members who are in position to profit by such advertising can, in this way, aid their respective societies at the same time that they are forwarding their own business interests.

The total number of pages of papers in the JOURNAL for 1895, exclusive of those contributed by the Western Society of Engineers, was 626. The year just past, with its 490 pages, shows, therefore, a reduction of 136 pages in the volume of papers submitted by the remaining societies, a reduction due, no doubt, to the continuance of the business depression of the last few years.

The increase of 60 cents (from $3.99 to $4.59) in the cost per page of the JOURNAL, is easily explained by the reduction in the number of pages, the total cost necessarily decreasing in much less proportion.

The following statistical appendices are submitted:—

Appendix A. Statement of receipts and expenditures during 1896.

Appendix B. Estimate of assets and liabilities at the close of 1896.

Appendix C. Detailed statement of cost of JOURNAL during 1896.

Appendix D. Comparison of mailing lists of the JOURNAL, at the close of 1895 and of 1896, respectively.

Appendix E. Statement of material in JOURNAL during 1896, by pages.

Appendix F. Comparison between operations and conditions during 1895 and 1896.

Very respectfully yours,

JOHN C. TRAUTWINE, JR., *Secretary.*

APPENDIX A.

STATEMENT OF RECEIPTS AND EXPENDITURES DURING 1896.

CASH, 1896.

Dr.

To Balance, January 1, 1896..................		$268 73
" Assessments:		
Boston Society of Civil Engineers......	$1,509 00	
Western Society of Engineers.........	35 50	
Civil Engineers' Club of Cleveland....	508 50	

Engineers' Club of St. Louis..........	$523 50		
Civil Engineers' Society of St. Paul...	105 75		
Engineers' Club of Minneapolis.......	113 28		
Civil Engineers' Club of Kansas City..	115 00		
Montana Society of Civil Engineers...	142 50		
Denver Society of Civil Engineers....	80 25		
Association of Engineers of Virginia...	63 00		
Technical Society of the Pacific Coast.	372 25		
		3,568 53	
To Subscriptions		594 34	
" Sales of JOURNALS......................		266 71	
" " " Descriptive Index.............		102 24	
" Advertisements		858 00	
" Sales of Reprints........................		194 75	
" Sales of Periodicals......................		30 00	
" Electros ordered by Western Society.....		13 50	
" " " " "Fire and Water"...		4 50	
" 25 copies Boston mailing list..............		1 75	
" Linotype metal returned.................		54 74	
" Interest on Deposits.....................		7 40	
			$5,965 19

Cr.

By Edward Stern & Co., Incorporated (Printers)......	$2,945 70	
" Illustrations	816 07	
" Secretary's salary.............................	600 00	
" Linotype composition, 1895......................	15 43	
" Index compilation...............................	175 00	
" Car fares......................................	1 10	
" Mimeographing, etc..............................	10 97	
" Discounts on subscriptions.......................	20 20	
" " " sales	11 70	
" Commissions on advertisements..................	94 75	
" Messenger service...............................	3 08	
" Stationery	3 57	
" Telegrams	1 42	
" Postage stamps..................................	27 02	
" 20 copies of Index bought.......................	30 00	
" Express and freight charges......................	5 25	
" Postage refunded................................	50	
" Furniture	41 71	
" Amount refunded................................	7 73	
" Stacking JOURNALS in cellar......................	6 00	
" Binding Vols. II-XIII, inclusive.................	12 00	
" Sundries	16 65	
		$4,845 85
" Cash balance, December 31, 1896.................		$1,119 34

APPENDIX B.

Estimate of Assets and Liabilities at the Close of 1896.

AVAILABLE ASSETS.

Cash balance, December 31, 1896		$1,119 34	
Less subscriptions for 1897, paid during 1896		51 00	
			$1,068 34
Amounts receivable from Societies (for assessments, etc.):			
Civil Engineers' Club of Kansas City	$79 01		
Montana Society of Civil Engineers	105 75		
Association of Engineers of Virginia	63 00		
Technical Society of the Pacific Coast	232 25		
		$480 01	
Subscriptions due:			
For 1896	108 00		
" 1895	21 00		
" 1894 and earlier	36 00		
		$165 00	
For Reprints		16 75	
" Advertisements		170 00	
" Sales of Journals		12 70	
" " " Index		6 00	
" Copyright fee		1.00	
			$851 46
			$1,919 80

LIABILITIES.

Edward Stern & Co., Incorporated (Printers):			
Ledger balance	$174 93		
For December Journal	266 81		
" Reprints, etc	112 29		
		$554 03	
Am't to be refunded to purchasers of Indexes		4 00	
Electro-Tint Engraving Co		56 18	
Westcott & Thomson (Electrotypers)		3 15	
Engineers' Club of St. Louis		9 50	
Share of Western Society of Engineers in surplus of Association of Engineering Societies at close of 1895		23 00	
Share of Engineers' Club of Kansas City in surplus of Association of Engineering Societies at close of 1896		25 00	
			$674 86
Excess of Assets over Liabilities			$1,244 94

APPENDIX C.

Detailed Statement of Cost of Journal During 1896.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	E. Stern & Co. Sum of 1, 2, 3 and 4	Illustrations.*	Cost of Manufact'e Sum of 1 2, 6.	Wrappers.	Secy's Salary.	Sundries.†	Total.‡	No. of Pages.§	Cost per Page.
January	$99 05	$111 50	$6 20	$6 06	$222 81	$35 25	$245 80	$4 50	$50 00	$25 23	$337 79	86	$3 93
February	33 35	64 50	6 20	3 11	107 16	5 00	102 75	4 50	50 00	25 24	191 90	46	4 17
March	61 03	84 75	5 64	5 25	156 67	32 75	178 53	3 58	50 00	25 24	268 24	70	3 84
April	82 17	87 50	5 90	6 48	182 05	31 53	201 20	4 00	50 00	25 24	292 82	72	4 07
May	57 88	85 00	5 90	6 38	155 16	15 80	158 68	4 00	50 00	25 24	250 20	66	3 79
June	165 01	228 55	6 05	16 43	416 04	280 12	673 68	4 28	50 00	25 24	775 65	128	6 06
July	87 51	103 88	5 95	8 57	205 91	93 01	284 40	4 08	50 00	25 24	378 24	88	4 30
August	18 81	56 00	5 88	7 28	87 97	85 15	159 96	3 98	50 00	25 24	252 34	34	7 42
September	55 71	77 64	5 90	6 42	145 65	4 50	137 83	4 00	50 00	25 24	229 39	64	3 58
October	44 61	87 56	5 89	6 72	144 78	83 00	215 17	3 98	50 00	25 24	307 00	54	5 69
November	52 33	73 19	5 87	4 94	136 33	10 00	135 52	3 95	50 00	25 24	225 52	54	4 18
December	99 20	132 06	5 84	7 81	244 91	95 28	326 54	3 90	50 00	25 24	419 33	94	4 47
Totals and averages	$856 66	$1,192 11	$71 22	$85 45	$2,205 44	$771 39	$2,820 06	$48 72	$600 00	$302 87	$3,928 42	856	4 59

*The figures in column 6 include preparation of cuts and lithographic stones, and paper and presswork on insets.

†The figures in column 10 include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the Journal, and not embraced in any other column. They do not include the cost of preparing reprints of papers.

‡Sums of amounts in columns 5, 6, 8, 9, and 10.

§The figures in column 13 include 4 cover pages in each number and 16 pages in indexes to Vols. XVI and XVII.

APPENDIX D.

Comparison of the mailing lists of the JOURNAL, at the close of 1895 and of 1896, respectively:

	1895.	1896.
Boston Society of Civil Engineers	390	431
Western Society of Engineers	401	
Civil Engineers' Club of Cleveland	139	175
Engineers' Club of St. Louis	170	167
Civil Engineers' Society of St. Paul	32	35
Engineers' Club of Minneapolis	25	12
Engineers' Club of Kansas City	22	
Montana Society of Civil Engineers	64	67
Technical Society of the Pacific Coast	168	149
Denver Society of Civil Engineers	28	28
Association of Engineers of Virginia	38	42
	1477	1106
Extra copies to members of the Board of Managers, five each	80	80
Advertisers	23	23
Exchanges	122	108
Subscribers	215	241
Complimentary copies	18	14

Besides this, many copies have been sold and specimen copies sent out; and authors of papers have each received five copies of the JOURNALS containing them. Two thousand copies of each number have been printed.

APPENDIX E.

Statement of material in JOURNAL during 1896, by pages.

	Papers.	Pr'c'd-ings.	Chair-man's Report.	Adver-tis'm'ts.	Ind'xes to Vols.	Totals.	Cuts.	Plates and full-page cuts.
January	42	14	10	16		82	1	5
February	18	8		16		42	0	1
March	42	8		16		66	3	10
April	24	28		16		68	4	2
May	40	6		16		62	3	1
June	94	6		16	8	124	4	13
July	64	4		16		84	4	12
August	12	2		16		30	1	2
September	40	4		16		60	3	0
October	28	6		16		50	26	1
November	30	4		16		50	1	2
December	56	10		16	8	90	12	7
Totals	490	100	10	192	16	808	62	56
Covers						48		
Total						856		

APPENDIX F.

Comparison between operations and conditions during 1895 and 1896:

	1895.	1896.
Excess of assets over liabilities, December 31	$223 93	$1,244 94
Number of Societies in Association, December 31	11	9

Number of names on mailing lists of Societies in Association	1,477	1,106
Number of subscribers	215	241
Annual receipts from subscribers, @ $3.00	$645 00	$723 00
Number of advertisers	23	20
Annual receipts from advertisers	$679 84	$858 00
Total pages in JOURNAL	1,482	856
" " of papers	792	490
" cost of JOURNAL	$5,911 48	$3,928 42
Cost per page	$3 99	$4 59
Average number of copies issued monthly	2,383	2,042
Number of small cuts	116	62
" " plates and full-page cuts	66	56
Cost of illustrations	$859 60	$771 39

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XVIII. FEBRUARY, 1897. NO. 2.

ENGINEERING COMPENSATION.

BY M. S. PARKER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Address at the Tenth Annual Meeting of the Montana Society of Civil Engineers, held at Great Falls, Montana, January 9, 1897.*]

How seldom does the old and experienced civil engineer advise the young man about to begin his career in life to adopt the profession of civil engineering! To his brother engineers the reason is obvious. The practice of the profession does not offer pecuniary inducements commensurate with the study, hard work, and experience necessary to possess the title C. E. in its fullest meaning.

The preliminary education necessary for the civil engineer is not less than that required for any other professional calling, and the subsequent training is as exacting in its requirements.

The civil engineer, ripe in experience, has passed through an ordeal of preparation that should entitle him to the highest consideration among the professions and a proper remuneration for his services. Alas, how seldom is this the reward for valuable service rendered! The maximum compensation for engineering services is at best meagre when compared with the compensation for other professional service. The railways of the world have given employment to a large majority of the civil engineers during the past fifty years. There is probably no class of professional men who have rendered more valuable service to the world at large than the civil engineers employed in building the railroads, and

*Manuscript received February 15, 1897.—Secretary, Ass'n of Eng. Socs.

probably no class of men who have received less compensation for services rendered. The same amount of time, energy, and hard work expended in any other direction would bring to this class of men their well-earned reward.

How contrary is the experience of those employed in this great work of civilization! The compensation for such services is barely sufficient, with proper economy, to support a man with a family from month to month. Should disability or loss of position occur, there is no bank account possible to tide over any considerable loss of time. The engineer engaged in this line of employment loses touch with other branches of his profession. His main reliance is on railroad work. This means unsteady employment. The result is well known to engineers.

The plums are very scattering in the pudding. Permanent positions are few as compared with the transient positions. The ever-to-be-feared order for reduction of expenses is a constant menace to the quasi-permanent employed engineer, and makes his tenure of office very uncertain.

The architect, the near relative of the engineer, receives his compensation according to the magnitude of his work. The larger the sum of money to be expended under his direction, the larger the amount of his commission for services.

The lawyer receives fees according to the magnitude or importance of his case, and leads all professions in the matter of compensation for services rendered. The physician is rewarded for professional services according to his ability and experience. The physician having climbed the ladder of successful practice has no limit to his charges except his tender conscience. Running through the list of professions open to the young man, we find, for pecuniary success, the profession of civil engineering offering the least inducement of them all. For immediate results possibly the engineering profession is the leading one. The young graduate engineer secures almost immediately in times of prosperity a position that might be the envy of his fellow-student in some other profession, both for its responsibility and the accompanying pecuniary reward, but here such envy should cease.

Let us look ahead ten years. Should the young engineer have cast his lot among railway builders, he has acquired ten years of valuable experience in this line of work—knowledge that cannot be obtained except by such experience. His services have become more valuable to his employer, but his salary has not increased with his usefulness. The difference in compensation between the first position secured and the position after ten years is not ma-

terial, and we may add another ten years, and the difference is less proportionate.

One instance will illustrate this. A company proposes to build a railroad. An engineer is selected to locate the road. This selection is made with regard to the ability and experience of the engineer. The expenditure of millions of dollars is placed under his direction, relying on his ability and judgment to make the best selection as to location and the most economical expenditure of the money. The large expenditure is left almost entirely to his judgment, the projectors of such enterprises, as a rule, having little knowledge about such matters. His immediate superior is a chief engineer, whose duties are more of an executive and advisory nature. It may be said that the engineer in the field is the sole responsible person for the economic location and construction of a railroad. This engineer, having the expenditure of millions of dollars under his direction, has a great responsibility resting upon him, as all must admit. Mistakes in judgment can cost his employers large sums of money. The engineer who by education, experience, and ability is fitted to take this responsibility upon himself receives the munificent monthly compensation of possibly $200, seldom much more, and often less. This compensation for transient monthly service, his tenure of employment expiring with the completion of the work. In what other line of professional employment can be found a greater responsibility with so little pecuniary compensation? Americans are led to believe that they are the best-paid people in the world, and in most instances this is true. As applied to civil engineers, however, the statement is incorrect. In England the compensation for engineering services is far above the standard of the United States, and ranks the profession nearer on an equality with the other recognized professions. Wherein lies this poor appreciation of the services of the civil engineer in this country?

The author is led to believe it lies wholly with the members of the profession themselves. The tendency has been to depreciate the pecuniary value of their services. The present system of competitive bids for engineering service is one of the depreciatory measures in existence, and is very detrimental to the prosperity of the engineering profession, very demoralizing in its effects upon legitimate compensation. Such methods of obtaining professional service should be completely ignored by engineers as being unprofessional and beneath their dignity. An individual or corporation does not ask for bids for legal services. The individual in need of a surgical operation does not ask bids from surgeons to perform

the operation, neither does the head of a family ask for bids for medical attendance of his family for a period of time. How many reputable attorneys or physicians would so lower their professional standing as to enter into any such competition? Yet this is a growing practice in this country in acquiring engineering service. It is not difficult to comprehend where the encouragement of this practice will lead the engineering profession.

One instance that the author has in mind of the many that have come to his attention will serve to illustrate this practice. A Southern city desired to make extensive municipal improvements, establish a sewerage system, grades of streets and pavements, the entire improvement involving the expenditure of about four hundred thousand dollars. The city fathers had appropriated $15,000 for engineering expenses, including superintendence—a reasonable amount for the services expected. They then asked for bids for plans, specifications, and superintendence of the work projected. The Board of Public Works desired to engage a certain engineer of long experience and high standing to do the work, but under the resolution of the City Councils bids must be submitted for the required service. The engineer the choice of the board submitted a proposition, but not in the nature of a competitive bid—merely a reasonable offer for his services. What was the surprise of members of the board and the engineer selected on opening the bids to find offers from engineers who are recognized as authority upon such matters proposing to do the work for about one-half of one per cent. of the proposed expenditure, and about one-third of the sum proposed by the engineer chosen by the board. The bid accepted for the entire work was $2,200. This bid was from a prominent and well-known civil engineer of New York. There was such a gulf of difference between the lowest bid and the proposition of the engineer selected that, in the face of public opinion, the contract had to be awarded to the lowest bidder—a very erroneous practice in vogue among municipal corporations, as the sequel often proves.

Such methods of practice cannot be too severely condemned by the civil engineering profession. They lead to careless and inefficient work, and thus bring discredit upon the profession. What standing can be expected by the profession at large when its leading members so lower their professional dignity? Does it not place the profession on a par with a commercial body? There should be a code of professional ethics among civil engineers that would not tolerate such practice. Such practice should be stamped out in its infancy. To encourage it means the degen-

eration of the profession in the future. If executive ability, combined with knowledge of the science of civil engineering, is not to be appreciated in the engineer, why devote his life to it, when other avenues of life are open to him in which he may find honor and proper compensation for the faithful performance of his duties? There comes a time in the lives of all men when work is impossible. It is the duty of every man to provide against such time. Should the civil engineer be obliged to work his life through for the bare privilege of living from day to day, knowing that when health or strength fail him he is to become an object of charity? How many engineers recognize this fact as they advance in years, and seek to better their future financial condition by engaging in other more remunerative occupations? This is not done from choice, as the civil engineer loves his profession, but as a matter of necessity to provide against future want. This is a sad commentary upon the profession in this country; still, it is true. The poverty of engineers is proverbial. Is it strange that the old engineer advises the young man to avoid the profession and cast his lot in some other vocation?

The profession of civil engineering is as old as history. It is one of the most honorable and noble of callings. Its members have rendered invaluable service to mankind, and stand upon the roll of honor of the world's greatest benefactors, and it is greatly to be regretted that so noble a vocation should be so poorly rewarded in this world's goods.

It is not within the limits of these few remarks to go very far into this subject. The facts stated are familiar to engineers, and need no comment of mine to impress them upon their attention.

It is not my purpose to pose as reformer, simply to call attention to a few known facts, in the hope, at least, that the members of the Montana Society of Civil Engineers will do all in their power among themselves to raise the standard of professional honor.

THE PROBLEM OF DEEP WATER NAVIGATION THROUGH THE PASSES FROM THE MISSISSIPPI RIVER TO THE GULF OF MEXICO.

By J. A. Ockerson, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 20, 1897.*]

The waters of the Mississippi River, on their way to the sea, traverse a distance of 1,183 miles from St. Louis to the Head of the Passes. Here the river divides into three main passes, viz: Southwest Pass, South Pass, and Pass a Loutre. The latter branches out into Southeast Pass, Northeast Pass, and Pass a Loutre proper, through which the waters reach the Gulf. The Gulf end of the delta thus formed covers a width of about 40 miles.

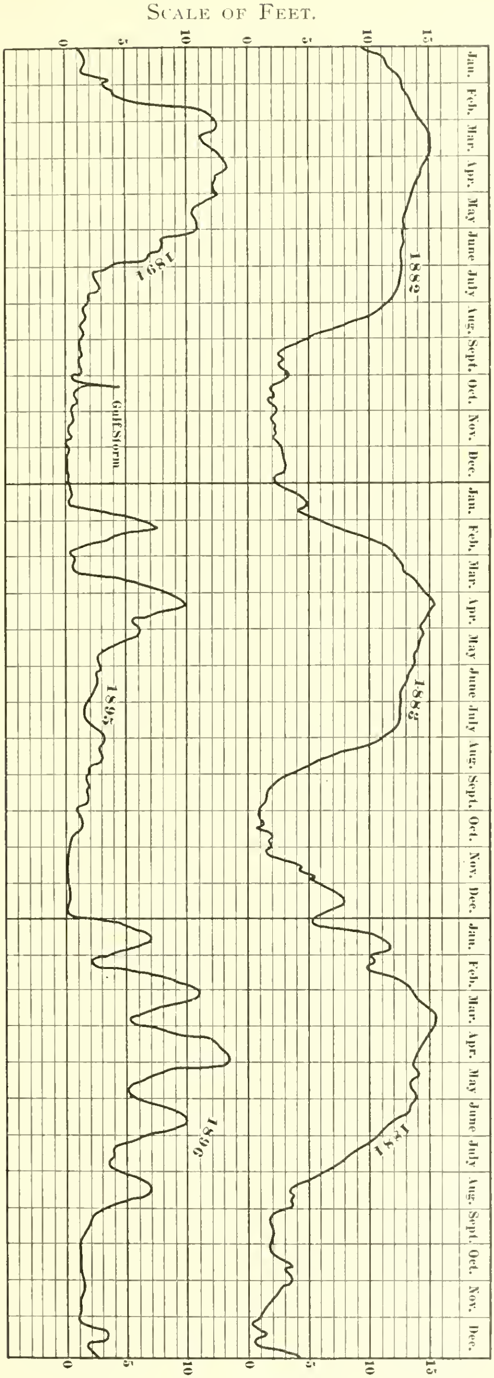
The mouths of all these passes are obstructed by bars formed by the deposit of sediment brought down by the river and dropped where the slackwater of the Gulf is met. The amount of this deposit is in a measure proportional to the amount of water carried by the pass.

The first definite account of the character of the several passes is to be found in the report of Captain Talcott, made in 1839. Southwest Pass at that time was reported as being 15.2 miles long. Its width at the head was 2,800 feet, and narrowed down to 1,200 feet, and again widened out at the mouth to 9,436 feet. The depth of water at the head was 48 feet, the greatest depth in the pass was 102 feet, and the average depth 70 feet. The depth over the crest of the bar at low water was 13 feet. The velocity of the current was 4.8 feet per second, and the discharge was 342,692 cubic feet per second, or 40 per cent. of the total volume of the river. In 1874 this pass was reported as 18 miles long and, on an average, 1,400 feet wide, with a least depth of 15 feet on the crest of the bar. The distance between the 30-foot contour in the pass and the same contour in the Gulf was 23,000 feet.

In 1894 the discharge was found to be 311,174 cubic feet per second, with a velocity of 4.2 feet per second. This is 42 per cent. of the whole volume of the river.

South Pass, in 1838, was reported as 11.3 miles long. The width at the head was 2,400 feet. It narrowed rapidly down to a width of 700 feet, which was about the average down to a point near the Gulf, where it again widened to 3,200 feet at the extremity of the land. The depth over the bar at the head of the pass was 19

*Manuscript received February 6, 1897.—Secretary, Ass'n of Eng. Socs.



HYDROGRAPH SHOWING STAGE OF RIVER AT CARROLLTON, LA., 114 MILES ABOVE HEAD OF PASSES.

feet, and the maximum depth in the pass was 53 feet, with 8 feet on the crest of the bar at the mouth of the pass. The velocity was 3.3 feet per second, and the discharge 80,761 cubic feet per second, or 10 per cent. of the total volume of the river. The banks were reported as being firmer and higher, and the trees of older growth, than in the Southwest Pass, thus indicating an older formation. In 1874 this pass was a little over 11 miles long, with an average width of about 750 feet. The maximum depth was 55 feet, and the distance between the 30-foot curve in the pass and the same curve in the Gulf was about 11,900 feet, with a least depth on the crest of the bar of 7 feet.

The discharge was reported as 57,000 cubic feet per second, and it was estimated that it carried 22 million cubic yards of sediment annually. The discharge in 1894 was found to be 55,198 cubic feet per second, with a velocity of 3.1 feet per second. This is 7 per cent. of the whole volume of the river.

Pass a Loutre runs in a northeasterly direction, and reaches the Gulf about 15 miles from the head of the passes. In 1874 it averaged about 1,700 feet in width, the distance between the 30-foot contours at the mouth being about 20,500 feet. In this length there was a pool over 30 feet deep for a length of about 3,000 feet, which reduces the length of the bar to 17,500 feet. The least depth on the crest of the bar was 9 feet. The velocity measured for this pass in 1838 was 3.9 feet per second, with a discharge of 467,571 cubic feet per second, or 50 per cent. of the total volume of the river. At the bar of the Pass a Loutre the discharge amounted to 170,527 cubic feet per second. The discharge of solid matter per annum was found to be 53,000,000 cubic yards.

The discharge of this pass in 1894 was 376,889 cubic feet per second, with a velocity of 4.2 feet per second. This is 51 per cent. of the whole volume of discharge.

Up to 1875, when it was seriously obstructed by mud lumps, Pass a Loutre was regarded as the most favorable pass for improvement, on account of its direction, which shortened the distance to Eastern ports some 40 miles, and on account of the bar being shorter and the entrance during storms being easier and safer.

Cubits Gap was made in 1862 by sailors, who cut a ditch to enable them to reach the fishing grounds in the Gulf. It is a pass of no mean dimensions. It is situated about 3½ miles above the Head of Passes, and it possesses one merit not found in the other passes: It is well above the wide shoal which covers the entrance to the passes. The width at the river is 3,000 feet, and the distance from deep water in the river to the 30-foot curve in the Gulf is

about 8 miles. The maximum depth at the entrance is 73 feet, but it shoals in a distance of half a mile to 13 feet, and this depth is about the average for a distance of 4 miles, when it grows gradually deeper. It will be observed that the distance from the main river to the deep water in the Gulf is very much shorter than in any of the other passes, although the bar is considerably longer. The entrance is as well protected from storms as the other passes, and it is also more directly in line with the great bulk of traffic.

Work has been done at the mouths of all the main passes for the purpose of increasing the depth of water over the bars. The first appropriation for improvement work was made in 1836, and amounted to $75,000, and it was followed in 1837 by another appropriation of $120,000. An elaborate survey was made of all the passes by Captain A. Talcott in 1838. A plan of deepening the channel by dredging with buckets was recommended, and the work was carried on with indifferent success until the appropriation was exhausted. No further work was done until 1852, when $75,000 was allotted to deepen the channel of Southwest Pass by stirring up the bottom. The contractor succeeded in securing a depth of 18 feet over the crest of the bar. This depth seems to have been ample for the shipping of that time. The Board of Engineers appointed to prepare plans for this work recommended several alternatives in case the stirring process failed, one being parallel jetties at Southwest Pass 5 miles in length and 14 feet wide, with piling 2 feet apart. In case all schemes to deepen the pass failed, then they recommended a ship canal at some suitable point above the Head of Passes.

The next appropriation was made in 1856, and amounted to $330,000, and a five-year contract was let to open 20-foot channels in Pass a Loutre and Southwest Pass, and maintain the same during the period covered by the contract. The plan of the contractors, Craig & Rightor, was to close the minor by-passes and build parallel or converging jetties at the Gulf end of the passes. Other bidders had proposed to open the channels by various stirring devices. A jetty about a mile long (5,735 feet), consisting of a single row of sheet piling supported at intervals with piles, was built from the extreme point of land on the east side of Southwest Pass out into the Gulf. This work was soon partially destroyed by storms, and was finally abandoned. Harrows and scrapers, aided in places by bucket dredges and blasting away the mud lumps, were then resorted to, and by the fall of 1858 an 18-foot channel was secured in both passes. An 18-foot channel was secured in Pass a Loutre after one month's work, the result being

credited to a free use of torpedoes, consisting of some 8,000 pounds of powder deposited on the surface of the bar in tin canisters.

As long as the stirring-up process continued the depth was maintained, but the contractors found the work more expensive than they had anticipated, and gave it up. In 1859 the propeller *Enoch Train*, provided with two screws and water ballast, by means of which the draught could be changed, was tried at Southwest Pass, but proved to be too frail for the work. Scrapers were also used, with no better success. The work again reverted to the Engineer Corps, who continued the harrows and scrapers and succeeded in keeping a channel open for a period of one year at a cost of $60,000.

The next appropriation was made in 1866, and amounted to $75,000. A contract was let to keep Southwest Pass open to a depth of 18 feet, 200 feet wide, but the boat and machinery provided for the work proved inadequate, and the contract was annulled without anything being accomplished. Early in the following year an appropriation of $200,000 was made for improving the mouth of the Mississippi. A steam dredge boat, the *Essayons*, especially adapted to excavating and stirring up the bottom by means of screws and scrapers, was designed and built at the Atlantic Works, of Boston. This boat began work on Pass a Loutre bar in July, 1868, and succeeded in increasing the channel depth from $11\frac{1}{2}$ to $17\frac{1}{2}$ feet. Considerable delay was caused by breaking the machinery, especially the blades of the excavating or propeller screw, which were frequently disabled. These defects were remedied by placing a plow in front of the screw to protect it, and the attachment of a scraper 18 feet long and 10 feet high, which could be lowered in front of the plow. A mud keel was also provided for the purpose of keeping the vessel straight on her course when at work. The scraper partially enclosed the screw so as to give an upward tendency to the material stirred up by the screw. In connection with this dredge, torpedoes were used to blow up the mud lumps, but they were utter failures. These torpedoes consisted of 60 pounds of blasting powder encased in an iron tube and sunk into the mud lump about 8 feet deep.

The work with the *Essayons* was so successful that in 1871 it was reported that for several months very few vessels had been detained on the bar, and that in all previous years a large fleet of vessels had been detained for weeks and even months. During the following year the dredge *McAlester* was completed by John Roach, of New York, at a cost of $218,300. This was used in connection with the *Essayons* in Southwest Pass and Pass a Loutre,

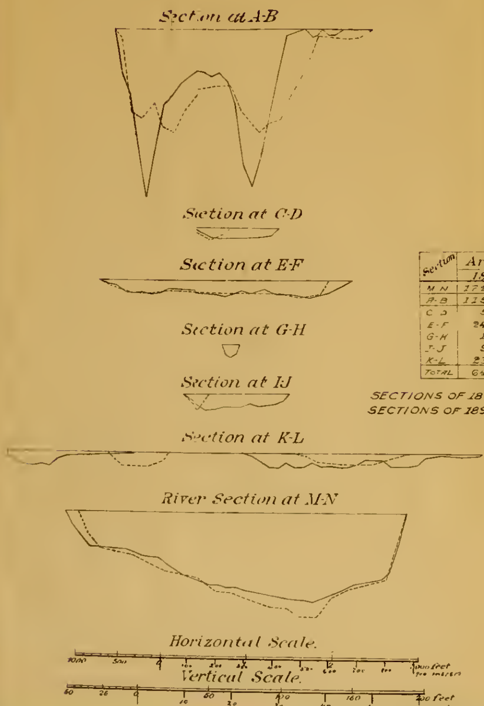
CUBITS GAP.

SHOWING

THE PROCESS OF DELTA BUILDING

AND THE CHANGES

IN THE FORM OF THE DELTA.

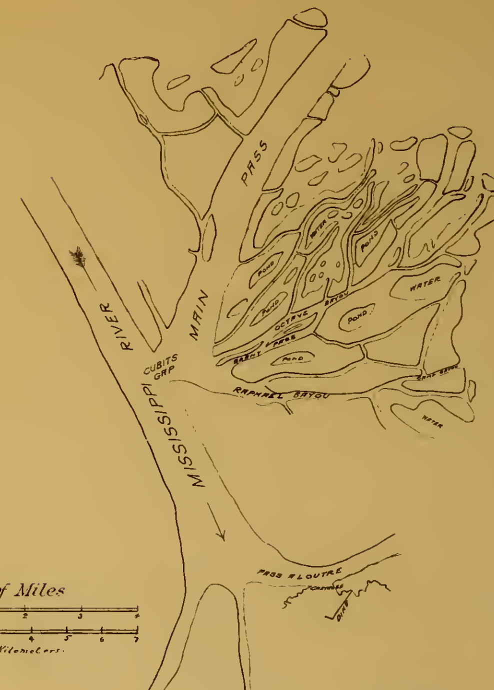


Section	Areas in sq.ft. 1876	1893
M-N	172,650	183,700
A-B	115,600	131,000
C-D	5,644	2,326
E-F	24950	22800
G-H	1,560	
I-J	9334	1760
K-L	23400	12222
TOTAL	64888	39108

SECTIONS OF 1876 SHOWN THUS: —— ——

SECTIONS OF 1893 SHOWN THUS: --- ——

NOTE:- SURVEYED IN 1876



NOTE:-SURVEYED IN FEB. 1892 BY
CHUCAS LEWIS, C.E. SURVEYOR

and in 1873 it was stated that the natural obstruction to the channel in Southwest Pass had been removed by the dredging and scraping system, and a 20-foot channel had been secured.

In April, 1875, the channel in Pass a Loutre was obliterated in a few hours by a large mud lump, which also partially closed Northeast Pass, and further work here was suspended.

Dredging in Southwest Pass was continued until August, 1877, when the results at South Pass, where the jetties were under construction, rendered further work unnecessary.

It will be observed that as early as 1856 it was regarded as important to have two improved entrances. During the period 1837 to 1878 a great number of devices for removing the bars were tried, and some two and a half millions of dollars were expended in their efforts to secure and maintain navigable channels through the passes. These devices covered a wide range, as may be seen in the following list. There were conical screws, screw propellers, water jets, scrapers and harrows, dipper dredges, wheel and bucket dredges, pile jetties, floating jetties, and torpedoes. There were also camel docks proposed to float vessels over, regardless of draught and depth of water. All of these failed, from one cause or another, except the combination propeller and scraper dredges *Essayons* and *McAlester*, and even these were not capable of maintaining a depth of more than 18 feet.

In the meantime the demand for greater depths came with the increase in size of vessels, and it was deemed advisable to attempt to construct permanent works which would give ample depth at all times for the largest vessels. For this purpose a board, consisting of three army engineers, three civil engineers, and one from the Coast Survey, was appointed in 1874 to devise some plan for securing the desired results. This board visited Europe and examined the works at the mouths of the Vistula, the Danube, the Rhone, the Rhine, and the Suez and North Sea canals. Their plans were matured and report rendered in January, 1875. The board recommended the improvement of South Pass with parallel jetties about 11,900 feet long and extending out over the bar to 30 feet of water, these jetties to be constructed of brush, fascines, and stone, the top width increasing from 10 feet near shore to 50 feet when 30 feet of water was reached, with slopes varying from one on two to one on four, according to the depth, the tops to be rounded and paved. Their estimated cost of such works, including dikes at Head of Passes, was $5,342,110. At this time the distance between 30-foot contours at the mouth of the pass was about 11,900 feet, with a minimum depth on the crest of the bar of 7 feet.

On the 3d of March, 1875, an act was passed authorizing James B. Eads and associates to "construct such permanent and sufficient jetties and such auxiliary works as are necessary to create and *permanently maintain* a wide and deep channel." This channel originally contemplated a depth of 30 feet, 350 feet wide, but this was modified in 1878 and 1879 to a channel 26 feet deep, 250 feet wide, with a central depth of 30 feet. For this the contractor received \$5,250,000, and \$100,000 per annum from July 8, 1879, for a period of 20 years, for maintaining said channel.

Including these items, the total expended on the improvement of navigation at the mouth of the Mississippi River to date amounts to about \$9,500,000, or an average for 60 years, since the first appropriation, of \$158,333 per year. The average cost during the past 20 years has been about \$360,000 per year, or about \$150 for each vessel that passes through the jetties.

The Eads jetties, as they are called, are built very nearly on the lines recommended by the Board of Engineers. They are parallel, and the original lines were 1,000 feet apart. A second pair of jetties were built inside of the first lines and 800 feet apart, to contract the channel and prevent the river water from escaping. The channel was still further narrowed by spur dikes, so that the clear width now is only 600 feet. This contraction was found to be necessary in order to secure the required scour.

The old jetties were surmounted by a concrete wall 5,453 feet long, consisting of foundation blocks 20 feet long, 4 to 12 feet wide, and 3 to 3½ feet thick. This was capped by a parapet 3 to 4 feet wide and 2½ to 4 feet high. It was partly of rubble stone laid in cement mortar and partly of concrete. It formed a perpendicular wall 5½ to 7½ feet high, resting on a base 4 to 12 feet wide.

On October 11, 1886, a severe storm demolished the parapet on the east jetty to such an extent that it was necessary to construct a new one. This work was begun in February, 1889. The new wall was built on the inner side of the old wall and on the old mattress, which was supplemented by new mats where needed, and then covered with stone about 2 feet deep, laid as evenly as practicable. This brought the foundation about up to average flood-tide, and on this was constructed a concrete parapet. The river side of this parapet is vertical; the top width is 3 to 4 feet, and the slope on the seaward side is one on one. The height averages about 3 feet. The surface was smoothed up with cement mortar. Gibbs' Portland and Alsen's German cement were used. The sand and gravel came from a point on the river some 260 miles above the works. The riprap was granite and hard limestone. At high

tide, when there was a swash sea, burlap was laid over the riprap to prevent the cement from running through before setting. The concrete was mixed on a barge with a Cockburn mixer.

In 1894 the new wall went safely through one of the most violent storms that have ever visited that locality.

At the present time the inner end of the east jetty is covered with deposit for a distance of about 4,000 feet, and the west jetty is covered for its entire length.

It has been found necessary to resort to dredging at intervals to secure the required depth over the bar. During the year ending June 30, 1896, dredging was required for 169 days. The channel has, however, proved ample to satisfy the demands of commerce, and no serious delay to vessels has occurred since it was first opened.

While the bar at the mouth of the pass was the main obstruction, there was another bar at the head of the pass with a depth of only 17 feet on the crest. This necessitated the construction of extensive dikes at the head of the pass and a mattress sill across both Southwest Pass and Pass a Loutre for the purpose of diverting the water into South Pass, as the volume of water was thought to be too small for the scouring effect required. Through this bar the contract required a channel 26 feet deep and 200 feet wide.

In 1891 a break occurred in the right bank of Pass a Loutre, about one and a half miles below the head of South Pass. Several efforts have been made by the legal representatives of the late James B. Eads to close this break, as it bids fair to reach such magnitude as to materially diminish the flow through the other passes, and hence become a menace to navigation. The crevasse is now some 2,220 feet wide, with a maximum depth at the entrance of 60 feet. It flows into Garden Island Bay, which is quite shallow, the average depth being about 6 feet. A dike 8,350 feet long was built in shallow water for the purpose of closing the crevasse after previous efforts had failed. This was destroyed by a violent storm when nearly completed. The dike was rebuilt and strengthened with sheet piling, but was badly wrecked by a second storm, which occurred in October, 1894.

The dike consisted of two rows of piling 16 feet apart, with the piles in each row 8 feet apart and projecting 9 feet above water. The piles in each row were stiffened by a 4 x 8 inch stringer fastened with drift bolts to the piling about 6 feet above water. Half the length of the dike was in about 9 feet of water, and the remainder in from 1 to 4 feet of water. A continuous foundation mattress about 3 feet thick was built, suspended between the rows

of piling and sunk in place by means of temporary weights made of railroad iron. Once on the bottom, the mattress was held in place by braces made of scantling extending down from the waling pieces to cross binders on the mat, and the weights were then removed. On this foundation mat loose willows were placed between the rows of piling. These were compressed as much as practicable and then fastened in place by cross-pieces placed under the walings and spiked to each side of the piling at each bent, and thus connecting the two rows of piling. They were also weighted down with sacks filled with earth. The top of the willows was about 5 feet above the water when the dike was completed. The sheet piling that was used consisted of sawed timbers 8 x 12 inches and 35 to 55 feet long. Waling pieces 8 x 8 inches were bolted to the piling on both sides near the top. The piles were made with tongue and groove by means of strips spiked to the narrow face of the piles.

After the destruction of the above work the project of closing the crevasse was abandoned.

The shoaling in South Pass has been attributed to this crevasse as the primary cause. It has been observed for some years that the pass channels deteriorate at low water and scour out at high water. For more than three years the usual high-stage effects are lacking, owing to the fact that the river has not reached a high-water stage during this period. While the crevasse undoubtedly has considerable effect on the depth of water in the pass, the deficiency can readily be accounted for by the long period of low water, and doubtless much of the obstruction will be scoured out during the next high-water period. The decrease in depths through South Pass is also due in some measure to the destruction of the training dikes at the head of the pass.

Whatever may be the effect of the Pass a Loutre crevasse, the relation between the stage of river and scour or fill, as developed by observations extending over a period of years, shows conclusively that stage, as effecting the eroding and silt-bearing power of the current, is the controlling factor in the matter of channel depths. The high-stage effects of 1882-3-4 were so active and eroded the bed of South Pass to such an extent that works were planned to prevent further enlargement of the pass channel.

Judging from past experience, it may be said that during periods when low-stage effects predominate for considerable time the force of the current cannot be relied upon to carry the vast volume of sediment out to deep water in the Gulf, but at such times it must be supplemented by dredging in order to secure a depth sufficient to satisfy the demands of navigation.

The Pass a Loutre crevasse, if allowed to flow, would ultimately form a delta in Garden Island Bay similar to the one formed by Cubits Gap. The volume of flow would rapidly diminish as the delta extended seaward, and its influence as a factor in the maintenance of navigable channels through the passes would vanish.

The diagrams relating to the growth and decadence of Cubits Gap well illustrate this process. They are also interesting as showing the process of delta-building in a comparatively short space of time. The discharge through the gap at one time amounted to 34 per cent. of the total volume of the river. At the present time it hardly amounts to 10 per cent.

A strong effort is being made to secure from Congress a sufficient sum of money to permanently close the Pass a Loutre break, so as to prevent the threatened damage to the channel through South Pass.

In 1875, when the jetty work began, the total number of vessels reported as passing both out and in was 2,159. There were 1,307 sailing vessels and 852 steam vessels. The total tonnage was 1,569,161 tons. The revenue on imports amounted to $2,214,-571.84. Twenty years later, with a channel depth increased from 18 feet to 30 feet, the record stands as follows: Number of entrances and clearances, 2,397; number of sailing vessels, 170; number of steam vessels, 2,227; total tonnage of above, 4,873,562 tons; revenue collected on imports at the port of New Orleans, $1,719,-815.75. To this should be added the duties collected at St. Louis, San Francisco, and other interior points which receive goods via New Orleans. The value of exports for the fiscal year ending June 30, 1896, was $80,986,804. Of this, cotton is the largest item, amounting to over $64,000,000. Corn exports amount to something over $7,000,000. The imports for the same year amounted to $15,945,836, or a total of imports and exports amounting to $96,932,640 per annum.

It will be seen from the above that the tonnage of individual vessels has increased very much, and that the number of sailing vessels has diminished. With an increase of about 10 per cent. in the total number of vessels, the tonnage has increased to more than three times the former amount. The tendency to increase the size and draught of vessels has probably not yet reached its limit, and this, taken in connection with the increase in imports and exports, may in the near future require a better outlet to the sea than is now found in South Pass.

The proposition to improve Southwest Pass is already being

discussed. The demands of commerce in this respect must be satisfied, and it is none too soon to begin investigations as to the best method of meeting the requirements. This becomes especially pertinent, as the contract for maintenance of the South Pass channel expires in July, 1899.

Can South Pass be further improved so that it will at all times be equal to any demands of commerce? Is it desirable or necessary to utilize one of the other passes for improvement and also maintain the present channel so as to avoid the possibility of blockades due to grounding of vessels or damage to channels by storms? If so, which pass promises the best results for the least outlay? In view of the experience at South Pass, which shows that the works deteriorate rapidly and require a large annual outlay for maintenance and that jetties must be supplemented by dredging, are we justified in attempting to construct so-called permanent works on foundations which are continually subsiding, and are racked by storms, all tending to make the work of maintenance difficult and expensive? What form of construction and what character of materials are best adapted to the works required? In view of the extraordinary improvement in the capacity of dredging machinery, would it not be practicable to rely largely on dredging to open and maintain a channel? What width and depth are necessary in order to provide for easy and safe navigation for the largest vessels for some years to come?

None of these questions can be satisfactorily answered without careful study by competent engineers, preceded by an exhaustive survey covering all of the passes and including a critical examination of their physical characteristics at various stages of river and tide. Some of the pertinent questions are: What direction and with what velocities do the waters enter and leave these passes at different stages? What amount of sediment do they carry, at what stages are deposits made, and when does the maximum scour occur? What effect do the prevailing Gulf currents and winds have on the deposits at the mouth of the passes? How long are the bars which obstruct the inflow of the water at the head of the passes and the discharge at the mouth of the same? What is the controlling depth on these bars? What is the volume of water carried at different stages? Which pass shows the firmest banks, the least tendency to elongation from deposits, and the least liability to obstruction from mud lumps or sand waves?

All of these items have a very important bearing on the selection of a proper site for carrying on successful works of channel improvement. The questions propounded are not easy to answer,


MAP OF THE
MISSISSIPPI RIVER DELTA
SHOWING LOCATION OF CREVASSES
AND
IMPROVEMENT WORKS
Scale
NOTE.
Figures show depths at mean low water in fathoms, except on dotted areas, where the depths are given in feet.
The soundings shown were taken as follows:
Main river above head of Passes in 1872; North Pass and approaches in 1860.
Approaches to South West Pass in 1871; Approaches to Pass à Loutre.
North East and South East Passes in 1872; South West Passes and Pass à Loutre in 1867; Cubits Gap in 1877; Grand Bayou in 1884, and South Pass in 1896.
SOUND
EADDY'S BAY

and it is important that work looking to their solution should begin as soon as practicable, so that the results will be available before it becomes necessary to take up the work of construction. With the proper study of the various phases of the problem involved, the engineer may begin the work of guiding and controlling the forces of nature with confidence in his ultimate success.

The solution of the problem is of vital importance to the entire Mississippi Valley. The entrance to a stream that, with its tributaries, affords 15,000 miles of navigation must be kept free from obstructions, so that vessels coming from all parts of the world can have safe and easy access to the surplus products of our manufactories and our fertile fields.

The writer is indebted to Major James B. Quinn and C. Donovan, in charge of work at the jetties, and J. D. Crawford, Deputy Collector of the Port of New Orleans, for much valuable information, and to the United States Coast Survey for the main part of maps of the delta.

RESISTANCE OF SHIPS AND OTHER FLOATING BODIES AT DEEP AND SHALLOW DRAFTS OF WATER.

By Joseph R. Oldham, N. A. and M. E., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, January 26, 1897.*]

"Ah, could we but fathom the mighty deep and count up the treasures there!"

I am inclined to the belief that many of our yachtsmen, master mariners, and others have had racing craft constructed using a very small draught of water, with the idea of gaining speed, and indeed it would seem that up to a few years ago there were naval architects who avowedly designed yachts to float lightly immersed, so as to lessen the surface friction and to be more easily propelled. So firmly is this conviction impressed on the minds of some of our marine experts that I fear nothing less than experiments conducted some fifty miles under the sea would convince them of their error; but, even were this accomplished, the same authorities might still prove obdurate, for there it might be that sunken vessels would float again, for water at such a depth would, I think, be a very different fluid from that which we now see carried in ships' bottoms or in locomotive engine tanks. When water has a pressure, say of over 10,000 pounds per square inch, as it may have at the bottom of the deep oceans, its bulk must be considerably reduced, and consequently the surface friction experienced by a body moving therein would probably be increased. With this admission, which is based largely on the imagination, I will ask you to bear with me while I cite a less popular opinion regarding the friction of solid bodies moving in water.

I hope that this subject will not prove tedious to you, and it should not if discretely treated, for Sir W. H. White says: "No branch of naval architecture has a richer literature" than that which forms the subject of this paper.

It would be a formidable task to merely enumerate the names of eminent mathematicians and experimentalists who have endeavored to discover the laws of the resistance which water offers to the progress of ships, and still more formidable would be any attempt to describe the various theories that have been devised. Again and again has the discovery of the form of least resistance been announced, but none of these have largely influenced the

*Manuscript received February, 1897.—Secretary, Ass'n of Eng. Socs.

practical work of designing ships, nor can any be regarded as on a thoroughly scientific basis. In fact, a century and a half of almost continuous inquiry has firmly established the conviction that the problem is one which pure theory can never be expected to solve.

The experimental tank for ascertaining the resistance of the wave-making qualities of ship models has proved to be the most valuable adjunct of the scientist when confronting the multitude of mistaken theories advanced from time to time in connection with ship resistance. For instance, the popular idea was that a fish or other similar body moving through the water experiences resistance mainly and primarily because it has to force the water out of its way as, for instance, our straits car-ferry boats have to do with thick ice in Winter. Until thirty or forty years ago, the accepted theory of ship resistance, so far as there was any, was based upon this mistaken notion, the resistance being supposed to be due to the inertia of the water disturbed. According to the now universally accepted theory, however, in an imperfect fluid, such as water, a fish or torpedo would experience resistance solely by virtue of the frictional imperfection of the fluid, and the degree of resistance would be (at least broadly speaking and presumably) proportional to the degree in which that frictional quality was present. Mr. Froude concluded by saying that in an ideal, perfectly frictionless fluid *there could be no resistance at all, whatever the shape of the body.* The resistance experienced by a plane passing through water is equal to the weight of a column of the fluid, the base of which is equal to the area of the plane and height equal to the space through which a body would fall by gravity to acquire that velocity, and is thus expressed:

$$\frac{V^2}{aw \times 2g}$$

where a=area of plane,
w=weight of a cubic foot of fluid,
V=velocity in feet per second,
2g=twice gravity.

The resistance with which the ship meets is a compound of minute currents. The velocities of these eddies against the hull are proportionate to the velocity of the ship and her model. At ten knots per hour the eddy resistance is one pound per square foot of augmented surface and varies generally for other speeds as the square of the velocity. The bow, however, always experiences resisting pressure, as the square of its velocity of motion and requires horse-power as the cube of the velocity to overcome resistance. It is found experimentally that the resistance which the total surface of a vessel suffers in passing through the water varies

nearly as the square of the velocity, so that if the pull on a rope to draw a vessel through the water at a velocity of five knots an hour be equal to a weight of one ton, then at ten knots an hour the pull will be equal to four tons. In one case, therefore, the mechanical effort requisite to propel the ship during the hour is represented by a weight of one ton gravitating through a height of five knots, and in the other case by a weight of four tons gravitating through a height of ten knots, so that the power imparted in the respective cases is in the proportion of 5 : 40 or 1 : 8. In other words, while the resistance varies as the square of the velocity, the power necessary to be imparted per hour or per day will vary as the cube, so that to double the speed of a steam vessel the engines must exert eight times the power. They will therefore consume eight times the coal in the hour, but as with a double speed the voyage will only last half the time, the quantity of coal consumed per voyage and of power exerted will only be four-fold. The power consumed, therefore, in performing any given distance will vary as the resistance, which is four times greater with a double speed, but the power consumed per hour will be twice this amount, as in the hour a double distance is performed. If the velocity be increased three times, the resistance will be increased nine times, and the engine power to propel the vessel must be increased twenty-seven times, and so on in similar proportions.

While, however, this is the approximate law, it is not absolutely correct, and it is subject to various modifications in practice from causes to which regard must be had before sound conclusions can be reached. Water is perfectly frictionless, and has no sliding angle; it may carry foreign matter which can cause attrition, but it has of itself only the quality of adhesiveness, which gives rise to a certain sort of viscosity. The term friction as connected with water should be done away with in mechanics. These statements, I think, are both strong and weighty, and should, if time permitted, call forth earnest discussion. As I propose to make a short comparison between the friction of fluids and solids, it may tend to elucidate the comparison if I briefly quote one or two writers on the law of friction. Templeton says: "When no unguent is interposed, the friction of any two surfaces (whether of quiescence or of motion) is directly proportional to the force with which they are pressed perpendicularly together." This you will observe is the very reverse of the most approved friction theory bearing on water. Again he says: "When an unguent is interposed the amount of friction is in every case wholly independent of the extent of the surface in contact, so that the force with which two

surfaces are pressed together being the same, their friction is the same whatever may be the extent of their surfaces in contact," yet we are told that the increased force or pressure of water has no effect on the friction of a solid moving in it. The friction of motion was formerly considered to be wholly independent of the velocity of the motion, but the results of recent experiments by the Institution of Mechanical Engineers on friction of lubricated bearings shows that the *resistance of friction increases with the velocity*. This you will observe is in accord with the most recent experiments on *fluid* resistance. But to return for a moment to the friction of solid bodies, Mr. A. E. Seaton says: "*Friction is independent of velocity*, so far as movement through a fixed distance is concerned, that is, if a body be moved through 10 feet the friction is the same if the movement takes place in one second of time or in ten seconds; but if time be taken into account the friction of moving the body ten times over the ten feet in ten seconds is ten times that of moving it once in ten seconds. In a marine screw engine for instance, making seventy revolutions per minute, the friction is seventy times that of one revolution, and consequently if a side wheel engine, having the same size cylinders and working with the same pressure of steam, makes only thirty-five revolutions per minute the friction of the journals will be half that of the screw engine."

Our literary friends do not appear to be quite in accord with regard to the laws governing the friction of solids, so you must not be surprised if some of them get out of their depth when they touch on friction in deep water. When quoting Mr. Seaton, whom I know very well, I cite the opinion or conclusions of a thoroughly scientific and practical marine engineer whose training was by no means purely academic, moreover that author was educated in a very similar school to that in which Sir E. J. Reed, Sir W. H. White and Dr. Froude, received their early impressions and in addition to such advantages Mr. Seaton has had the most valuable experience in the engine works and shipbuilding yard. I place stress upon this because I believe that though a scientific training is of great importance it may be immeasurably enhanced by touching or handling the materials of which an engineer's designs are to be constructed, so I would suggest that his writing receive due consideration. Mr. Seaton says that, "war ships require a larger amount of horse-power per square foot of wetted skin than ships of the merchant navy. This was thought to be due to the extreme beam for the length. As a rule the ratio of length to breadth in the merchant service is much larger than in govern-

ment vessels, and because the speed constants of the latter are much lower than those of the former, it was urged that long narrow ships were much easier to drive than broad ones; but this is not necessarily true, and the cause of the difference between the two types is not far to seek when carefully looked for. The ships of the government navy, as a rule, *draw more water* for their displacement than do merchant steamers, and the keel and the bilge keels are nearer the bottom, so that the average pressure per square foot of their surface is very large compared with merchant vessels.

"The friction of the water per square foot of surface will depend on the *pressure directly*, so that the resistance from a square foot near the water line is very different from one twenty feet below it. The success of torpedo boats depends almost wholly on their lightness of both hull and machinery, enabling them to do with so small displacement that they literally skim over the water, and the pressure per square foot of wetted skin is consequently very small. Unless small boats are made to float at a very light draft they cannot be driven at high speeds. And all experiments with fast river steamers have shown this." This seems so reasonable and so natural that I think it calls for some moral courage on the part of an ordinary essayist to question the absolute accuracy of the assertions, and if the frictional resistance of fluids were governed by the same laws as solids, the truth of Mr. Seaton's statements would be self-evident; but such of course is by no means the case. From this it would seem that some authorities have confused hydrostatic pressure, due to deep immersion, with the dynamic conditions incidental to motion. Dr. Elgar appears to entertain a different opinion on this subject, for he says: "With regard to the effect of draught of water upon speed, we know that a limited draught is, as a rule, unfavorable to speed; that is, if you take a ship drawing twenty feet of water and load her down to twenty-five feet, it will usually take less power per ton displacement to propel her at twenty-five feet draught than at twenty feet, so that *shallow draught of water is unfavorable to speed.*"

This statement is the very antithesis of Mr. Seaton's writing.

Water, as you know, is practically incompressible. Can an incompressible fluid cause increased resistance to a solid body passing through it in proportion to the hydrostatic head? It seems to me that it cannot. On the other hand let us for a moment consider compressible fluids such as air or steam, the energy of which depends on the changes in temperature and volume. It appears clear beyond a doubt that air-ships would meet with less

frictional resistance near the top of Mt. Blanc, than near the surface of the Thames River during a November fog, for there the air would be heavier and denser, and a cubic foot would be heavier on London Bridge than the same bulk at the altitude of the Italian observatory. Again, steam at ninety pounds pressure would cause greater resistance to a moving body than at fifteen pounds, but a bulk of the former would only occupy about one-sixth of the space of the latter. Now as water occupies the same space, at least at all moderate depths, and as sixty-four pounds will always occupy one cubic foot space at a constant temperature, it should follow that water cannot augment its own frictional resistance by reason of the deeper immersion of that body within it. It may require, the greater power to separate the water at the fore-foot of a "Great Eastern" than at the load-line of a torpedo boat, but that portion of a vessel's resistance must not be confused with skin or surface friction. Place a board near the top of a deep bale of cotton and a child might draw it out, but in a much lower position, perhaps neither you nor I could draw it out, and that because the friction would increase in proportion to the load, but a pound of cotton at the bottom of the cart occupies much less space than a pound at the top.

On the contrary a pound of water at the top of a high water cart occupies just the same space as a pound of water at the bottom, so you see that the friction of solids and the friction of fluids or liquids are not analogous. But let us see what the eminent naval architects have to say on the subject. Quoting Mr. Froude, Sir W. H. White, referring to a thin plate with a plane surface immersed in water and moved end on or edgewise, says: "If the plate were immersed *very deeply,* it would create little or no surface disturbance, and therefore require *less force to propel it* at a certain speed than would a plate of equal immersed area, moving at the surface with a portion situated above that surface. If there were no surface disturbance, the resistance would be *practically independent of the depth of immersion.* In other words, if there be no surface disturbance the resistance at any speed is independent of the depth." Mr. W. P. Stephens says that the hydrostatic pressure increases with the depth, but as far as the motion of a fish or a yacht through the water is concerned, this increased pressure has no effect whatever, nor should it have, as it is balanced or the same in all directions. *Pressure has no effect whatever on the friction of the water upon the solid,* which is the same at all depths, so that the surface friction per square foot of keel would be the same on a vessel drawing thirty-five feet as on one only drawing five

feet, though the pressure in salt water would be as 2240 : 320. To examine this in a more practical way, I cite the performance of two single screw steamers of similar lines when each was steaming at the rate of 17 knots. The "Servia" is of 10,960 tons displacement at 23¼ feet mean draft of water; she steams 17 knots per hour with 10,300 indicated horse-power. This speed is attained with only .94 of a horse-power per ton displacement. The "Lancashire Witch" is of 1,020 tons displacement at 10.5 feet mean draft of water, and she steams 17 knots per hour with 1860 indicated horse-power, so she requires 1.82 horse-power per ton displacement. In other words, the shallow draft steamer requires double the horse-power per ton displacement, though she draws less than half the water of the deep steamer, and is of proper dimensions for the speed named. The one is subject to a pressure of 4.5 pounds per square inch, and the other to nearly 10 pounds per square inch. Here is a torpedo boat drawing only 4.5 draft of water, displacement 66 tons, indicated horse-power 700 at 20 knot speed. At this shallow draft not less than 10.6 horse-power is required per ton displacement.

These illustrations may not carry conviction with them on account of the great difference in dimensions of the vessels, but if they tend to prove anything it is that a shallow draft of water is unfavorable to high speeds. Let me read you a few lines by an eminent writer bearing on animal life at the bottom of the ocean, which I think will tend in some degree to elucidate my subject.

There is an enormous pressure, reckoned at about ten tons per square inch in every 1,000 fathoms, which is 160 times greater than that of the atmosphere we live in. At 2,500 fathoms the pressure is thirty times more powerful than the steam pressure of a modern locomotive when drawing a train. As late as 1880 a leading zoölogist explained the existence of deep-sea animals at such depths by assuming that their bodies were composed of solids and liquids of great density, and contained no air. This, however, is not the case with deep-sea fish, which are provided with air-inflated swimming bladders. Some deep-sea fish have two parallel rows of small circular phosphorescent organs running along the whole length of their bodies, and as they glide through the dark waters of the profound abysses they must look like model mailships with rows of shining portholes. If one of these fish, in full chase after its prey, happens to ascend beyond a certain level, its bladder becomes distended with the decreased pressure, and carries it, in spite of all of its efforts, still higher in its course. In fact, members of this unfortunate class are liable to become victims to the

unusual accident of falling upward. Even the ground sharks, brought up from a depth of no more than 500 fathoms, where the pressure would be about 1,300 pounds per square inch, expire before they gain the surface.

This tends to convince me that frictional resistance is not augmented by depth or pressure of water, for if it were, no fish could propel itself when subjected to a hydrostatic pressure of say, twenty-five hundred pounds per square inch of surface, as it would be when swimming at a depth of a little less than one thousand fathoms.

If the friction increased according to the augmented draft of water it would increase in the same ratio as the pressure increases, but this I think is not the case, for divers have been known to work and move about at a depth ot about 200 feet below the surface, where the pressure would be nearly 90 pounds to the square inch. This is about fifteen times the pressure existing at 14 feet, so I cannot conceive how a man could move his limbs to any advantage if such movements were subject to fifteen times the friction experienced at a moderate depth.

Divers worked in recovering specie from the hold of the Alphonso XII., at a depth of 160 feet of water, at which depth the pressure per square inch would be 67 pounds, that would cause a total pressure on the diver's body of about 100 tons. If the friction increased in the same ratio as the pressure I cannot believe that men could have done any useful work there, as they were only able to remain at that depth for about five minutes at a time. To cite a homely illustration bearing slightly on the subject, I may refer to swimming; many of us no doubt are swimmers and amateur divers, in which exhilarating exercise we may have gone down below the surface a distance of about three or four fathoms. My experience reminds me that there is no more difficulty in moving the limbs or in swimming swiftly at a depth of about twenty feet than at the surface of the water. If frictional resistance increased with the augmented depth, such I am confident would be perceived when swimming at a considerable depth below the surface. Does it not appear that the friction on a body moving in water is quite independent of the depth at which it moves? Suppose we compare two shallow draft and too deep draft steamers by the expression:

$$\frac{D^{2/3} \times S^3}{\text{I.H.P.}}$$

The following are the particulars of two torpedo boats drawing less than 6 feet, mean draft of water:

displacement (D) = 300 tons,
speed (S) = 30 knots per hour,
indicated horse-power (IHP) = 5220.

$$\text{then } \frac{300^{2/3} \times 30^3}{5220} = 232.$$

The second example has a displacement of 247 tons, speed 27.9 knots, indicated horse-power 3,990,

$$\text{then } \frac{247^{2/3} \times 27.9^3}{3990} = 211.$$

The speed efficiency of the Campania, though drawing four times as much water, is just about as high as the first example,

$$\text{thus } \frac{15{,}000^{2/3} \times 22^3}{28{,}000} = 231.$$

The Oregon drawing 24 feet of water has a higher constant than the second example,

$$\text{thus } \frac{11{,}000^{2/3} \times 18.3^3}{13{,}300} = 228.$$

Here is a boat of very shallow draft and yet her coefficient is extremely low,

$$\text{thus } \frac{66^{2/3} \times 20^3}{700 \text{ IHP.}} = 190.$$

Her speed is 20 knots, displacement 66 at $4\frac{1}{2}$ feet draft of water.

By the above comparison you will readily see that the higher the coefficient, the greater is the efficiency with regard to speed through the water. The performance of the deep draft steamer is just about equal to one shallow draft boat, and the performance of the second deep draft boat quoted is higher than the other shallow boat's. So by this comparison also, it appears that the resistance at any speed is independent of the depth.

It appears to me that shallow draft is decidedly unfavorable to high speed efficiency because the surface disturbance or water raising capacity per ton displacement will be much greater in a shallow draft than in a deep draft vessel. I think that we may now conclude that nothing is gained with regard to speed by twin screw and other steamers floating on comparatively shallow drafts of water, as frictional resistance is the same at all depths.

I have now reached my objective point which was to bring out the very diverse convictions or opinions held by eminent scientists and engineers on the resistance offered by water to ships floating therein, this I have done rather with a view to stimulate discussion of what I have been taught to consider a most important subject, for I am not able to present any startling original discovery which would settle this much discussed subject on a sound basis.

A few general remarks bearing on the dynamical conditions affecting floating bodies in motion before concluding may not be out of place. Water is not termed a perfect fluid; its particles do not move past one another with absolute freedom, but exercise a certain amount of rubbing or what is called friction upon one another, and upon any solid past which they move. According to Mr. Seaton, a ship moving forward has to displace a mass of water of the same weight as itself, and the water has to fill in the void which would otherwise be left by the ship. The work done here is measurable by the amount of water, and since it is equal to the displacement, displacement becomes a factor in the calculations of resistance, hence the adoption of the expression $\frac{D^{2/3} \times S^3}{\text{I. H. P.}}$. But to effect this displacing and replacing of water with the least amount of energy, it is necessary to do it gently to set the particles of water gradually in motion at the bow, and let them come gradually to rest at the stern. If it is not done gently, and the water is rudely separated, a wave is formed on either side, showing that energy has been spent in raising the water above its normal level. Although every ship, however well designed to suit the intended speed, causes these waves of displacement, it is the object of the naval architect to reduce their magnitude as much as possible. It has been the want of reflex action of the power in a parting wave, or rather the want of an appreciation of its loss, that has caused Froude and others to wonder that a ship of "perfect" form should require more power than that necessary to overcome "skin friction" to propel her. At high speeds wave-making becomes a very important factor, and the total resistance frequently varies at a higher power of the speed than the square. When the screw or side wheels first commences to revolve, the ship makes no headway, and it is only after some seconds have elapsed that motion is observable. The engine power has, during that period, been employed in overcoming the resistance to motion which all heavy bodies possess, and which is called the vis inertia. When the engine is stopped at the end of the voyage, the ship will continue to move, and come gradually to rest unless otherwise retarded by the reversal of the engines or by check ropes. The ship is then said to have "way on her," a phrase which, in scientific language, means that she possesses kinetic energy or momentum, which is given out, when the engine is stopped in overcoming the resistance of the water to the passage of the ship through it. This energy was stored up at starting in overcoming the inertia, and remains stored there until there is a retardation of velocity. In this way the

weight of the ship helps to preserve a uniformity of motion, as that of a fly-wheel does to an engine, therefore it is important that tug-boats should have weight as well as power, to prevent towing in a jerky fashion so often observable. When the vis inertia has been overcome, the power of the engine is directed on overcoming the resistance of the water, and wind if there be any. As the speed increases the resistance much more increases until it becomes equal to the power of the engines, and then the motion of the body becomes uniform, and though moving with even greater velocity it is as completely in equilibrium as when it was at rest. Thus the motive power is not now required to maintain motion, but to maintain equilibrium with the opposing resistance, for the body being inert has no power of itself to alter that state, thus the equilibrium is stable whilst the power and the resistance remain unchanged.

TRIAL TRIPS IN SHALLOW WATER.

As we reside on the banks of the shallowest of the Great Lakes* it may be interesting to learn a little more about the effects of shallow water in retarding vessels, especially high-speed steamers. Professor Rankine estimated that the loss caused by shallow water waves would be sensible, even when the depth of water was five-twelfths of the length of the wave, and at a depth equal to one-third the length it would become marked, increasing rapidly with shoalness. An example or two will emphasize this.

Suppose a ship to have a speed of 20 knots, and to be accompanied by waves of equal speed, which would be about 225 feet long from crest to crest. Then, by Rankine's rule, as much as fifteen fathoms in depth would exercise a sensible check upon the wave motion, and consequently increase the resistance of the ship; while water from twelve to thirteen fathoms deep would cause a very serious "drag." If the speed were only fourteen knots, the corresponding wave length would be about 110 feet, by Rankine's rule (five-twelfths of length) the retarding effect of about 8 fathoms would correspond to that of 15 fathoms in the 20-knot ship. These examples emphasize what was said above respecting the growing importance of shoalness in view of the high speeds now attained. Increase in speed in a vessel of a given size being accompanied by this necessity for greater depth of water in order to prevent serious retardation, it will be obvious that when increase in size and draft accompany increase in speed, that necessity becomes even greater. When a ship is driven at a speed where

*The depth of water between Cleveland and Detroit varies from 12 to 5 fathoms.

the resistance increases very rapidly with increase in speed, then the retarding effect of shoalness becomes more marked. Passage in shoal water then results in a serious check to the speed, and frequently there is a marked change and increase in height of the wave phenomena surrounding her.

The effect of relative shoalness of water has been very marked on the speed trials of some recent ships. A few examples out of many may be given. A torpedo-gunboat of the Navy was run twice on the same measured mile on the same day. At high tide she attained a speed of 17.8 knots, whereas at low tide the speed for the same horse-power was fully half a knot less. The maximum depth of water was about 9 fathoms, and the minimum about 7 fathoms. On the measured mile in Stokes Bay, H. M. cruiser "Edgar" required 13,260 H. P. to attain 20.5 knots in 12 fathoms of water, and was accompanied in this shallow water by considerable wave phenomena. In water 30 fathoms deep the wave disturbance was much less, and the ship attained 21 knots with 12,550 H. P. On the trials of the cruiser "Blenheim" during the first hour, the depth of water was mostly about 9 fathoms, and the engine made 92.5 revolutions, and developed 15,750 H. P., the speed of the ship being 20 knots. Under these adverse circumstances, the wave phenomena were more striking and unusual. Later on during the same trial the ship ran for two hours in water from 22 to 36 fathoms in depth, the same power was developed by the engines as in the first hour; but, in consequence of the greater depth of water the engines made 96.5 revolutions, and the speed rose to 21.5 knots. These examples illustrate the necessity for selecting measured distances having an appropriate depth of water, if the results of speed trials are to be trustworthy.

WATER SUPPLIES IN SOUTHERN CALIFORNIA.

By J. L. Van Ornum, Member of the Engineers' Club of St. Louis.

[Read before the Club, February 17, 1897.*]

This study is a result of personal observation and investigation in the San Gabriel and San Bernardino Valleys, California, eighteen months ago. While it contains examples of all important methods of development applicable particularly where the conservation of water is especially important, as the impounding system at the Bear Valley Dam, the development by submerged dams, as in Verdugo Cañon, the method of using temporary dams, as illustrated by the Riverside Water Co., the collection of the underground flow by means of pipes with open joints as employed by the Los Angeles City Water Co., the development of artesian wells, as in the San Bernardino supply, the use of ordinary wells, as at El Monte, the utilization of springs and surface flow of cañons, as employed by some of the towns of San Bernardino on the west, still the chief mode of development is by tunnelling, a mode more extensively used here than in any equal extent of territory in the Republic, and perhaps in the world.

A consideration of the physical characteristics of the region is necessary to a clear appreciation of these works. The Sierra Madre are the culminating physical feature of Southern California. They extend for about one hundred miles east and west and are from perhaps twenty to forty miles broad, north and south. Their elevation varies from five or six thousand feet, at their western limit, to nearly twelve thousand at their highest point, which is reached at Mt. San Bernardino and at Greyback, near their eastern end. Ruggedness and steepness of slope are peculiar characteristics of these mountains. While covering a considerable area, the valleys included between their ridges and peaks are generally quite elevated and their slopes are not at all uniform from the center to the circumference. They present rather the appearance of a great elevated mass reaching at their edges immediately an elevation approaching to the elevation of the whole range. In other words, from a plain about them they present the appearance of a great mountain mass whose immediate walls approach surprisingly near the perpendicular. There being, as a rule, no intervening ranges between the Sierra Madre and the sea, they act

*Manuscript received February, 1897.—Secretary, Ass'n of Eng. Socs.

really as a barrier to the moisture-laden clouds which come from the Pacific Ocean, causing them to precipitate on the seaward slope nearly all the moisture they hold. The prevailing winds being from the ocean, this side of the mountains is that which holds the rainfall. After passing the Sierra Madre, these prevailing winds have lost nearly all their moisture, and, as a result, beyond them on the north is the great Mojave Desert extending to the Sierra Nevada, on the east and southeast is the great Yuma Desert extending to the Colorado River and Mexico. In these deserts the rainfall is not more than two or three inches per year.

The Sierra Madre is throughout its extent so complicated and precipitous that nowhere occurs a pass with the exception of the Cajon Pass a little east of its center, through which extends the main line of the Santa Fe Railroad. Eastward of this pass the range is narrower than to the west. Westward of Cajon Pass the mountains present the appearance of two nearly parallel ridges with a very elevated succession of valleys between. The opening of these interior valleys is through the southern ridge, making tributary to the plains on the south the larger part of the mountain range as a source of water supply. On the south of the Sierra Madre lie the San Bernardino and San Gabriel valleys which are considered in this paper; on the southwest is the San Fernando valley.

Below the foothills of the Sierra Madre the plain has a very steep slope for a distance of three or four miles, varying from fifty to two hundred feet or more per mile. Beyond this steeper slope the inclination becomes much more gradual and is increasingly so as the sea is approached. The rivers and streams, like all those of a semi-arid country, are the largest at their sources, and as a rule disappear soon after reaching the plains. During the rainy season the volume of water is at times very great, and under these conditions the surface flow extends far into the valleys and even to the sea, but as a rule during most of the year whatever water there is below the mountains is underground. In the valleys the streams are generally not much below the general surface and are frequently very wide, the larger river courses being frequently a mile or more in width. These dry river beds are of course waste lands, consisting of sand and gravel on the lighter slopes and stones and bowlders, sometimes of a large size, where the steeper slopes occur next to the mountains. The soil in general in the valleys is very rich and productive, varying from the moist lands of the river bottoms and near the sea to the dry, but rich and lighter soils of the higher parts of the valleys.

The rainfall of the valleys is comparatively light, averaging from ten to fifteen inches per year for the lower part of the valleys, while at the base of the mountains it is in the vicinity of twenty inches. As the higher altitudes are reached the rainfall becomes still greater, reaching a maximum at the culminating region of the Sierra Madre of forty inches or more per year. For the whole southern slope of the Sierra Madre the rainfall averages from twenty to thirty inches per annum. A peculiarity of the rainfall (which is noted by Wm. Ham. Hall in his work on "Irrigation in California") is its concentration on mountain and hill points and passes. The city of Los Angeles is situated at such a pass at the outlet of San Fernando valley, with hills and mountains extending from it in different directions. It receives a downpour of from eighteen to twenty-two inches. In the valleys surrounding, the rainfall is not much more than half this where the elevation is the same as that of the city, and it is not much more on the hills at an elevation considerably greater. The vegetation of this region is such as one would infer from the description of its rainfall. In the valleys little but cactus, sage-brush and other arid growths occur naturally and the immediate mountain slopes are comparatively bare. Timber large enough for commercial purposes is found only in the highest mountain valleys where the maximum rainfall occurs, and below this there is little that can be properly designated as a timber growth except the cottonwoods, sycamores and other such trees growing in the cañon bottoms.

The three valleys already named have each the appearance of a great ampitheatre, the San Bernardino valley being the easternmost. On the north and northeast of this valley lies the great wall of the Sierra Madre already mentioned, to the southeast are spurs of the San Jacinto Mountains, on the south are the San Jacinto Hills and Temescal Mountains, and on the west separating this valley from the San Gabriel are the Chino Hills and San Jose Hills, all these last mentioned groups of hills and mountains being collectively known as the Coast Range. This valley is really open only on the west, the surrounding mountains on the other three sides being high enough to intercept the rain-bearing clouds. Mr. Hall gives its extreme length east and west as 37 miles and its width 27 miles, with an area of about 524 square miles.

The main drainage artery of this valley is the Santa Ana River. Its head waters are in the high mountain valleys about Mts. San Bernardino and Greyback and the slopes for many miles are not great. On reaching the edge of the mountains these streams plunge from an elevation of more than four thousand feet through

precipitous cañons for distances of ten or twelve miles down to the eastern end of the valley, which has an elevation of eighteen hundred to two thousand feet. From this point the slope is at first very high, but is more and more modified as the river passes southwestward through San Bernardino valley until it breaks through the valley's edge in the Santa Ana Cañon of the Coast Range. All the drainage of this valley reaches the Santa Ana River before it leaves the valley, though the flow is usually underground. The San Bernardino valley is the best watered of all in this part of the state, the flow from its streams being often at the surface for several miles after they emerge from the mountains. From the margins of this valley, nearly to the line of its arterial drainage, water is obtained from the mountains. On the lower lying lands, however, the ground water is so plentiful and approaches so near the surface that it is easily obtainable by means of wells, and not infrequently its presence moistens the land enough so that no irrigation is necessary.

The San Gabriel valley lies immediately westward of the San Bernardino valley. It also has the Sierra Madre on the north and has the San Jose Hills on the east, the Puente Hills and San Gabriel Hills on the South and the San Rafael Hills on the west. Mr. Hall gives its greatest length from east to west as 23 miles and its width 11 miles, with an area of 195 square miles. In outline and general characteristics this valley is much like the San Bernardino, but its rainfall is greater since it is more open to the rain-bearing clouds, and yet it contains very little area of naturally moist lands. The San Gabriel River is the main artery of this valley, having its head waters far in the heart of the Sierra Madre, between the two parallel ridges before mentioned. The mountain course of this stream has no extended and elevated mountain valleys as has the Santa Ana River. Its upper course is rather a mountain cañon,—precipitous, tortuous and rugged throughout its whole mountain course. Debouching at the plain it flows through San Gabriel valley in a southwestern direction. Collecting, as it goes, all the lateral streams of the valley, it breaks through the hilly edge of the valley at Pasa de Bartolo at an elevation of about two hundred feet above the sea, having a fall of about four hundred feet in its course of less than twelve miles from the mountains. One other peculiarity of this valley must here be mentioned. Beginning at the extreme western edge of the valley at about its middle point north and south, and extending northeastward for a distance of perhaps ten miles, is a great fault in the earth's formation at an elevation of about six hundred feet above

the sea. North of this fault the slopes are great, the soil is porous and light. To the south of it the slopes are very gradual to the San Gabriel River, and the soils are heavy and dark. Both these valleys have been settled for nearly a century, and the Jesuit Fathers inaugurated systems of irrigation, remains of which can still be traced. The real development, however, of water supplies has been mainly within the last fifteen years.

Settling in the environment just described, the people who came to these most attractive valleys found that the problem necessary of solution to change these rich, but barren, lands to productive ones was the method of securing and applying the necessary water. This problem was decided in different ways, according to the particular surroundings of each case, as will be noticed.

The remarkable Bear Valley dam in the heart of the Sierra Madre needs no extended description here. It has an elevation of over six thousand feet, and the rainfall in this valley is relatively enormous, reaching sometimes an amount of one hundred inches per annum. The water-shed is forty or fifty square miles in area, and the dam was built in a narrow gorge near its western extremity. The engineer who constructed it gives the following dimensions: Width at base, 22 feet for a height of 16 feet (at this point it was narrowed to 8½ feet and carried to an additonal height of 48 feet); width at top, 3 feet, and the radius of curvature here, 335 feet; the span at the top is about 300 feet. The reservoir covers two thousand acres, impounding twelve billion gallons of water. The available flow is about twenty-five hundred miners' inches for a year. This dam was constructed in 1884 and 1885, and is remarkable for the boldness of its design. Most of the towns east of San Bernardino, as Redlands, Mentone, Highlands, etc., as well as the surrounding country, receive their water supply through the distributing systems extending from this reservoir. Mr. Copley, of San Bernardino, stated that the intention of the company owning the water rights in the Bear Valley was to build another dam, from which the water is to be led by a tunnel through intervening mountain spurs to the opposite side of the range, and so furnish a supply for the nearer portions of the great Mojave Desert.

The Verdugo Cañon Water Company is developing a low water flow in Verdugo Cañon by means of a submerged dam. This cañon is just outside the San Gabriel Valley on the west, and has an area of about twelve miles. Unlike most of the works in this region, this company is a mere association of water-users not organized under the Wright law. During the greater part of the

year there is a surface flow large enough to supply the consumers, but for a number of weeks the supply is short, thus necessitating artificial works. This dam was built in the bottom of Verdugo Creek, where the hills contract its bed to a width of about six hundred feet. The trench was excavated to a depth of from ten to twenty feet, and a centrifugal pump kept the ground water from interfering with the progress of the work. A pipe with open joints above the intended dam, and with tight joints below, was first laid, leading to the distributing system, and then a tight wall was built from the solid rock at the bottom to near the surface of the creek bed.

The water which supplies the city of Los Angeles comes from the San Rafael Ranch, which is situated at the outlet of the San Fernando valley, where the Los Angeles River breaks through the hills forming its southeastern margin. This supply system was designed to secure the underground flow of the Los Angeles River. It was begun in 1886 and finished in 1889. The collecting system consists of two lines of 24-inch sewer pipe laid with open joints nearly parallel to the river on its west side, at a distance from it of from eight hundred to twelve hundred feet. The length of each of these lines of pipe is thirty-six hundred feet, and they lead into an open well at the southern end. They are laid about twelve feet below the river bed, and their estimated flow combined is eight million gallons per day. Leading into the same collecting well there was constructed an open ditch leading to a lagoon farther from the river and containing many living springs. This ditch has since been replaced by two lines of 16-inch pipe laid in the same manner, each sixteen hundred feet long. These supplementary pipes have increased the flow about two million gallons per day. From the collecting well the water is piped seven or eight miles to the distributing reservoirs on the outskirts of the city, and from them into the distributing system. Although this paper deals properly only with water supplies, there is an interesting feature connected with the method pursued to keep the water in these reservoirs pure. The reservoirs are not covered, and consequently in the warm climate there is a tendency to luxurious plant growth. Mr. Mulholland said that after experimenting for a considerable time with different methods it was found that the most effective way to prevent the fouling of the water was to permit the growth of one particular water plant, which prevented the multiplication of all other noxious growths. The name of this plant was not known, but it was of a slender, fibrous structure, several feet in length. The inconvenience con-

nected with this method resulted from the fact that it was necessary to remove the plant itself by means of drag-chains and other similar devices. This procedure was necessary every six or eight weeks, when it reaches its maturity.

Some of the most desirable lands were the most difficult to supply with water. This refers to those nearer the base of the mountains, which are naturally very dry. The sub-surface flow being so far below the surface that it is entirely beyond reach, the all but universal method followed here is to develop the water forming the underground flow of the cañons by means of tunnels. The general principle followed in such construction is to start a tunnel at or near the surface level of a cañon, and to extend it in a direction up stream and parallel to the general axis of the cañon on an ascending grade of ten or fifteen feet per mile. These tunnels do not follow the devious courses of the cañon itself, but are rather straight in design, cutting through the rock walls of points projecting into the cañon and passing through the *débris* of the cañon's bed, where it successively encounters this broken material. By reason of its lighter grade the tunnel somewhere reaches the bed rock. Although the cañons have a considerable slope, the length of tunnel necessary to secure this result is often great, because of the depth of the sand, rock, and bowlders through which the underground flow passes onward and is ordinarily lost. The prevailing size of tunnel is simply that which can be most easily constructed, being about six feet high and four feet wide, and elliptical in shape. The portions of the tunnel which are constructed through solid rock need no lining, but where they pass through the gravel in the beds of the streams they are timbered as is necessary. But little construction has been effected for the last eighteen months, on account of the uncertainty concerning the constitutionality of the Wright law. The cost of tunnel construction has been surprisingly low, being lately $7 or $8 per foot.

The city of Pasadena secures its supply from collecting works at the Devil's Gate. This place is a gorge in the Arroyo Seco, about two miles west of the city. The gorge here is thirty or forty feet wide at the bottom, and seventy or eighty feet deep. The hills on the west are high, and the eastern side is formed by a promontory projecting into the stream from the Pasadena mesa. It is in this promontory where are built the Pasadena collecting works. The mouth of the tunnel is on the southern face of this promontory and at its bottom. It was designed to build the tunnel through the promontory for a distance of a quarter of a mile or more and parallel to the Devil's Gate and intercept the under-

ground flow of the Arroyo Seco at the upper end of this gorge. In fact, the tunnel was first so constructed, but the expected underground flow was not found. On further investigation there was found cutting through the promontory and parallel to the gorge an old channel of the Arroyo Seco, which had since become filled by detritus. It was suspected, from the lack of underground flow through Devil's Gate, that this flow passed through the detritus-filled channel. Consequently a branch tunnel was built extending from the one first constructed eastward across this ancient course. The surmise proved correct, and a flow of about 160 miners' inches was developed by this last branch, the total length of tunnel through which the flow passes being about one thousand feet. A mile or so below Devil's Gate, in the west side of the Arroyo Seco, are two tunnels which have since been built to increase the supply. These were designed to open up springs in the gravel banks by giving their flow less obstruction, and so increasing its amount. Each of these tunnels is nearly six hundred feet long, and increases the supply about one hundred inches. This water is pumped to the top of the mesa, whence it flows by gravity to join the general system. The city of Pasadena and the surrounding ranches are supplied from these sources.

Lamanda Park and the great ranches to the northwest are supplied from Precipice Cañon. This cañon furnishes a reliable supply, although its drainage area is only about three square miles. The supply here is derived from several different tunnels. The lower one is a few hundred feet inside the gorge, and starts as usual at the surface, extending for about eight hundred feet parallel to the cañon through solid rock. It then angles across the stream and intercepts the underground flow at bed rock, at a depth of thirty-five feet. This supplies the lower lands of the company. The second tunnel is about nine hundred feet long and entirely similar to the first. The third and fourth tunnels are only about eighty feet long, and are designed (as some of these tunnels are) to merely increase the flow of springs or seeps in the sides of the cañon by opening up the seams in the rock and following them in whatever direction they extend, thus giving a more uninterrupted and increased flow. Work has recently been progressing at the first tunnel by extending a branch designed to interrupt and develop the side flow of a detritus-filled gulch which seemed, from surface indications, to possibly carry considerable water underground. It happened that this opinion of the engineer was entirely right, for the day after these works were visited a flow of twenty inches was developed. An interesting feature connected

with these works is the device used by Mr. Craig, the engineer, to raise all the flow from the second tunnel to a higher level. The elevation at the mouth of this tunnel is too low to admit of the use of its flow where it was found desirable. Thirty or forty years ago there was constructed higher up the cañon a low dam to intercept the surface flow. A small tunnel was built here developing water, which was also held by the dam. This water was utilized to irrigate the old General Johnston Ranch, but the volume of the supply long since became inadequate. On account of its height of 370 feet above the second tunnel it was thought by the engineer that the head thus available could be utilized in raising the water from this tunnel the necessary thirty feet. This flow passes through a five-inch pipe, which at one point is contracted to about three inches. Just in front of this contraction there is placed in the center of the five-inch pipe a three-eighths-inch nozzle, through which passes the water under the 370-feet head, easily raising the whole flow of the second tunnel the desired amount.

The towns of Azusa, Duarte, and Covina, with the surrounding region, derive their supply from the same tunnel. This is in the San Gabriel Cañon, its mouth being about one mile above the entrance to the gorge. The tunnel is twenty-eight hundred feet long, cuts through the projecting ridges and crosses the river once where it is lined with crib-work of 8 by 8 inch timber. At its upper end it again reaches the river bed at a depth of forty feet below the surface. Although its first crossing was eighty feet above bed rock, it was hoped that on encountering the river the second time bed rock might be reached, but here it was found that that rock was sixty feet beneath. A side tunnel was constructed in rock parallel to the stream, from which two different spurs were driven across the stream, again hoping to encounter rock at a less depth, but with no better results. However, this second crossing developed a flow of about 150 miners' inches, and when more becomes necessary it is intended to extend the tunnel to at least another crossing of the stream. Of the flow developed, Azusa has six-tenths, Duarte three-tenths, and Covina one-tenth.

The supply of Pomona, derived from tunnels, is not extensive. There are here two small tunnels, one giving a flow of perhaps 100 inches and the other 150 inches. Its principal source is artesian wells, which furnish so important a supply near San Bernardino. Pomona has over one hundred wells, varying in depth from 150 to 180 feet.

The Ontario Development Works consist of a tunnel about four thousand feet long in San Antonia Cañon, developing about three hundred miners' inches.

The tunnel supplying the Grapeland Irrigation Company is not yet completed. It is of the usual plan, and extends at present about two thousand feet axially up the Lytle Creek Valley, where it reaches a depth of fifty-six feet below the surface, but bed rock has not yet been reached. The present flow is about 120 inches. This company has also a right to an uncertain proportion of the surface flow of Lytle Creek.

Lytle Creek is one of the few streams which has a continuous surface flow. In August, 1895, this amounted to perhaps three thousand miners' inches. Rialto and the surrounding country own ninety-six inches of this flow, and take whatever more they wish that is not otherwise claimed.

In Mill Creek Cañon there is a 200-foot tunnel which was built merely to open up a slight flow from a spring in the side of the cañon by following the seams in the rock. In this short distance the surprising flow of two hundred inches was developed. This happy result of developing a surface indication is not always attained. An example of poor success is furnished at Etiwanda, where the surface indications were good and a flow of two hundred inches followed development at first. However, this did not last, for the next year the supply failed. The reason in this particular case was probably an insufficient drainage area above.

This is a short description of the main tunnels developing water for a distance of forty or fifty miles along the southern foot of the Sierra Madre. They furnish water to ranches and towns, famous far and wide for their many attractions and advantages, which could not exist without such water development. When it is noted that perennial water is considered worth approximately $1,000 per miners' inch (a flow equal to one-fiftieth of one cubic foot per second), the real significance of these gushing rocks may be appreciated.

The line of the fault described in the first part of the paper furnishes water for a number of ranches along its course, as well as towns below it. The soil above the fault is very porous, and holds immense quantities of water, as it were, in a sub-surface reservoir, being dammed by the impervious material just below the fault. The volume and accessibility of this water may be judged by the experience of the Pasadena and Pacific Electric Railroad Company. Just north of the western end of the fault this company excavated a well eight by twelve feet in size and twenty-seven feet deep, the lower seven feet of which were in quicksand. A constant flow of water through a three-inch pipe is drawn from this well. Not far away is the Pasadena city sewer flushing well.

This is six by twelve feet in section, twenty-one feet deep, and just touches quicksand. On the evening it was visited the flow into the well from the imprisoned water was at the rate of $22\frac{1}{2}$ cubic feet per minute. The inflow is always greater in the morning than at evening.

About two miles east of the wells just described is the El Molino Cañon, which is a natural gully in the edge of the mesa just above the fault. Here are eight short tunnels, aggregating about eight hundred feet in length, all of which were driven into the gravel for the purpose of increasing the flow of previously existing springs. The aggregate flow is perhaps eighty miners' inches. Alhambra and the surrounding ranches are supplied from this source.

The town of San Gabriel, where is the old Jesuit Mission, is supplied from springs on the line of this same fault at the Wilson Ranch. Here there are no development tunnels. The town of East San Gabriel is supplied from an artesian well situated also on the edge of the mesa.

The region of this fault seems to offer a very promising field for artesian wells. The Shorb Ranch has developed such wells most extensively. This ranch has six artesian wells just north of the fault, averaging 130 feet deep. From just below the mesa tunnels are driven to the wells for an average distance of three hundred feet for the purpose of conducting the water by gravity from them to the distributing system. The wells themselves, however, furnish all the supply, which aggregates about one hundred inches. A well two thousand feet north and three hundred feet deep reached water at a depth of 240 feet, the water rising to within thirty feet of the surface.

A wholly distinct region of artesian wells is that in the vicinity of San Bernardino, where they vary from 60 to 120 feet in depth. San Bernardino itself is supplied mainly from such wells, and a number of towns west, as well as Colton to the south, are supplied from similar sources.

Riverside, the oldest extensive fruit-growing colony of Southern California, derives some of its supply from artesian wells, but by far the greater part of it comes from the surface flow of the Santa Ana River. This is diverted from the river bed near Colton by means of a surface dam of brush and stone. Permanent diverting works, in the shape of a crib dam, were first attempted, but floods completely destroyed them. Successive attempts were no more successful, and finally the temporary structure of brush was decided upon as the only practicable solution. Of course,

this temporary structure washes out with every succeeding flood, but as it costs only about four hundred dollars, the financial consideration is not great. The dam is only four or five feet high, and the water is led perhaps a third of a mile, where advantage is taken of an available head of six feet to furnish power for milling purposes. The self-registering gauge at the weir indicated a flow through the main ditch of about three thousand inches.

It was found impracticable to put any masonry dam in the Santa Ana River, on account of the great depth to bed rock. The nearest approach of solid foundation to the surface is thirty feet, and this location is far below the necessary site of a dam. Although the fall of the river in this part of its course is only about three feet per mile, it is found difficult to maintain permanent structures founded in this bed. A part of the water supply comes from the Gage ditch on the east bank, which is carried across the river on a flume seven thousand feet in length. This flume is supported by piles driven fourteen feet into the river bed. Since this was constructed, during one of the spring floods the whole river bed was moved down stream to at least fourteen feet in depth, in such a way as to carry two bents of the trestle seven feet laterally. This movement was effected without disturbing the perpendicular position of the piles or the level of the flume at their top. Another local peculiarity is seen from the present method followed in lining the Riverside Canal. This method was discovered in the attempt to decrease the great expense of the lining with six-inch stone and mortar which was first used. It is found that the only necessary precaution required to prepare the earth to receive the three-fourths inch layer of mortar directly is to spray the banks with a water jet, in order to form an irregular surface to which the mortar will cling. The lining of canals prevents the growth of vegetable matter in them, which otherwise is very troublesome, except when sand occurs in suspension to prevent this. Usually, however, the water is clear, and the lining of the canals obviates the trouble and expense of cleaning them every fortnight. Wherever the surface slope necessitated a fall in the line of a canal great difficulty was encountered in preventing the wave motion resulting as an impulse from the falling water. This wave motion was very destructive to the canal banks which were not lined. The most practicable method for preventing this seemed to be the construction of a sort of well into which the water might fall and the waves expend themselves here before flowing onward in the canal. It was found difficult to adequately line these walls to prevent the caving of the canal banks, and its undue enlargement.

The timber work put in for this purpose was invariably destroyed. Other attempted solutions also failed. Finally the water itself solved the difficulty. In one case where the falling water had been left to its own devices the company's engineer found that it excavated its own proper pit, which did not enlarge beyond a certain small extent, and now the company lets the water take care of itself, merely lining the sides to a depth of eight feet below the surface. At one place where there is a fall of forty feet the falling water formed a natural bottom, at a depth of seventeen feet, which the water-cushion of the pit maintains in a constant position.

The above account describes the principal water-supply systems of these two California valleys. The towns and ranches of the coast plain (between them and the ocean) generally have a much simpler problem in securing their water. The lands are moist, and the drainage arteries from these valleys just mentioned carry great quantities of water easily obtained either from the surface or sub-surface flow. The cities of Santa Ana, Orange, Anaheim, etc., get their supplies in these ways.

Although the water supplies of the lower parts of the valleys and plains are not so extensive nor so vitally necessary as in the district first mentioned, yet such developments are everywhere intimately associated with the growth and prosperity of all this most lovely region where sunshine holds chief sway, though water is king.

Association
of
Engineering Societies.

Organized 1881.

Vol. XVIII. | MARCH, 1897. | No. 3.

ADDRESS BEFORE THE MONTANA SOCIETY OF CIVIL ENGINEERS.

By John Herron, Retiring President.

[Tenth Annual Meeting, Great Falls, Montana, January 9, 1897.*]

The constitution of our society provides that the address of the retiring President at the annual meeting shall be a summary of engineering progress during the preceding year.

I have thought it best to limit so much of these remarks as may apply to engineering progress to works in our own state, under control, in great measure, of members of our own society.

The President's address shall also contain a statement of the general condition of the society. This necessarily would be a *résumé* of or comments on the annual reports of the Secretary, Librarian, and Treasurer. I shall, in connection with this provision of the constitution, confine myself to calling the attention of our members to certain needs of the society and of the duties owed it by individual members.

While in the country at large there has been a dearth of engineering projects, our own state shows considerable progress in the way of permanent improvements.

The limit of life of timber structures and the increased demands of traffic and competition have combined to transform our railroads from temporary makeshifts, begotten by rapid construction in an unsettled country, to an appearance of stability and permanency.

*Manuscript received February 15, 1897.—Secretary, Ass'n of Eng. Socs.

THE NORTHERN PACIFIC RAILWAY.

During the past year the Northern Pacific Railway has been actively engaged in the improvement of its permanent way in Montana. In addition to the filling up of several small trestle bridges, three of the larger timber trestles have been replaced by steel structures. These are:—

1. *Greenhorn Gulch Viaduct,* 17 miles west of Helena; length, 579 feet; height, 95 feet. This is a deck girder, with 31-feet tower spans and 57-feet open spans. Total weight, 191 tons. The pedestals and abutments are entirely of concrete, including bearings and caps of pedestals.

2. *Austin Gulch Viaduct,* 19 miles west of Helena; length, 493 feet; height, 95 feet, with same general construction as the viaduct at Greenhorn Gulch. Both these structures are on a 2 per cent. grade and 10° curves.

3. *Flathead River, near Perma Station.* This bridge consists of four 180-feet through steel spans. The total weight of the structure is 339 tons. The abutments and piers are of concrete, some of the piers being over 30 feet high.

The work of lining the Mullan Tunnel has also been completed the past year. This work was described by Mr. H. C. Relf, a member of this society, in a very interesting paper read before the society, February 10, 1894, and published in the transactions in August, 1894. Probably the most interesting feature of this year's work was the portals, each being of monolithic concrete construction.

Work similar to that done at Mullan Tunnel is now being prosecuted at Bozeman Tunnel, the walls being of concrete, with brick arch. This tunnel is about 3,650 feet long, and probably one-half of the masonry work will be completed this year.

Other work being prosecuted this year in the state, but which will not reach completion, is: Three 155-feet through spans and one 56-feet deck-girder span over the Yellowstone River, near Merrill; two girder spans of 70 feet and two of 75 feet over the West Gallatin River at Central Park Station, and one 155-feet through span over the Thompson River at Thompson Falls.

THE GREAT NORTHERN RAILWAY.

During the past year the new terminal yards at Clancy and Woodville have been completed, and the rate of grade against west-bound traffic east of Clancy has been reduced from a maximum 1.5 per cent. to an equated 0.85 per cent. This work re-

quired the making of 66,000 cubic yards of embankment and the removal of 12,000 cubic yards of excavation, covering a distance of 3.66 miles of line.

The work of filling the trestle bridges between Clancy and Butte requires the placing of 684,000 cubic yards, of which 198,000 were put in, and the completion will dispose of 9,500 lineal feet of wooden bridges on that section.

To provide waterways for the above, in addition to work done in previous years, there were constructed stone box and brick arch culverts of sizes from 3′ x 3′ to 8 feet arches, amounting to 3,000 cubic yards of stone masonry and 210,000 brick, to lay which required 2,000 barrels of Louisville cement. The stone was about one-half sandstone from the Great Falls quarries and one-half granite from the Boulder quarry. The brick were made by Kessler, of Helena.

Other waterways for filled bridges were constructed of cast-iron pipes, of which there have been placed during the past season 3,064 lineal feet, in sizes varying from 24 to 54 inches in diameter, with a total weight of 535 tons.

The more important waterways which are being or have been replaced by permanent bridges are the following:—

1. Bridge 98, the Corbin Viaduct, a steel structure; length, 672 feet; height above masonry, 96 feet; twelve spans 32 feet, two spans 48 feet, three spans 64 feet; weight, 449 tons. Foundations: Great Falls sandstone laid in imported Portland cement, amounting to 236 cubic yards. The superstructure is designed for a live load of two 136-ton consolidation engines and a dead load equivalent to weight of structure + 450 pounds per lineal foot. This bridge is on a 10° curve and a gradient of 1.8 per cent.

2. Bridge 164, three miles east of Butte; steel structure; length, 400 feet; height, 79 feet; eight spans 32 feet, three spans 48 feet; total weight, 225 tons. Foundations: 286 cubic yards of Boulder granite laid in Portland cement.

3. Bridge 166, two miles east of Butte; steel structure; length, 399 feet; height, 43 feet; one span 16 feet, two spans 20 feet, one span 23½ feet, six spans 30 feet, three spans 34 feet, and one span 37½ feet; weight, 185 tons. Foundations: 310 cubic yards of Boulder granite laid in Portland cement.

The spans of all these bridges are deck-girders.

THE ANACONDA COMPANY'S HOISTING ENGINES.

A very important addition to mechanical advancement in the state has been the construction of two hoisting engines for the

Anaconda Company, at Butte, which are among the largest engines used for hoisting purposes in the world. They were built by the Union Iron Works, of San Francisco. Each engine consists of one left-hand and one right-hand compound beam engine, connected with the reel shaft by disc cranks. The cylinders are vertical and inverted. There is one high pressure, 26 inches in diameter, and one low pressure, 46 inches in diameter, for each engine. The pistons are connected with the opposite ends of the beams by piston rods, cross-heads, and links. At the top of each beam one of the main connecting rods takes hold, while the opposite end of the rod is attached to the crank-pin, which will give a positive stroke of 72 inches to the pistons.

There are two reels on the crank shaft, each having a capacity of about a mile of ½″ x 8″ wire rope, whose breaking strain is more than 200 tons. They can be operated independently of each other or in balance, as desired. Auxiliary engines are used for working the reel brakes, reel clutches, reversing gear, and disc brakes, and to handle one of these engines in all of its requirements the engineer has to use one foot and seven hand levers.

These engines weigh approximately 400 tons each, and develop 2,200 horse-power at 60 revolutions per minute. They will hoist a load of 32,000 pounds at the rate of 2,000 feet a minute.

The designing of the engines was superintended by the engineering department of the Anaconda Company.

THE GAGNON ELECTRIC RAILWAY.

The Colorado Smelting and Mining Company, of Butte, has, during the past year, done away with the wagon haul of its ores from the mine to the smelter by the construction of the Gagnon Electric Railway. This interesting work has a total length of 2.7 miles. At the Gagnon terminal is a tunnel 254 feet long through the waste dump. This tunnel is on a 70° curve, and has a grade of 3 per cent. At the reduction plant terminal the concentrator bins are approached on a trestle with a grade of 2 per cent. and a 65° curve.

The maximum grade for loaded cars going out of the tunnel is 3 per cent.

Empty cars returning up Montana street have a maximum grade of 10.62 per cent. This grade is from Park street to the mouth of the tunnel, and is operated by an electric hoist plant of two 15-horse-power Sprague double reduction motors established at the mouth of the tunnel. A cable is attached to the cars at the tunnel, which is the summit of the 10.62 per cent. grade, and the

cars are then let down as far as Park street. At this point the cable is detached, and the cars proceed to the reduction plant under control of the trolley and brakes, having then a maximum down grade of 7.46 per cent.

The cars are of ten tons capacity, and are operated in pairs. Each is supplied with two 15-horse-power motors, and the power is furnished from the city electric plant.

Track and wheel brakes are on each car, but the wheel brakes are ordinarily sufficient to control them, the track brake being used only in emergencies. The electric hoist will also probably be done away with, as the combination of the two brakes is found to be efficient, even on the 10.62 per cent. grade. The line is owned by the Butte Consolidated Street Railway Company, the ore being hauled by them under contract with the Colorado Company. Mr. F. W. Blackford, member of the Montana Society of Civil Engineers, had charge of the construction of the line.

WATER-POWER PLANT AT GAYLORD.

The Parrot Silver and Copper Company, of Butte, Mont., has had under consideration a canal, 18 miles long, leading from a point on the east side of the Jefferson River nearly opposite the old town of Iron Rod to the new town of Gaylord, in Madison county.

The canal has a cross section of about 125 square feet. The ordinary section on table land is 20 feet wide at bottom, 30 feet wide at top, depth 5 feet, with the lower levee raised 2 feet above water level. The slope in the cutting is 1 to 1; on the levee, $1\frac{1}{2}$ to 1. The cross section in rock on steep side hills is 10 feet in width, carrying 8 feet of water, with a slight excess of grade to compensate for the diminished area.

The grade has been $2\frac{1}{2}$ feet per mile. This is rather excessive for so large a canal, but was adopted with a view to being able to work it hard, should occasion require, by protecting the lighter soils with some kind of rip-rap.

The quantities of classified material moved have been:—

Solid rock	12,000	cubic yards.
Loose rock	37,000	"
Earth	288,000	"
Total	337,000	"

About 350,000 feet of lumber have been used in flumes, bridges, head gates, and overflows, and something over $15,000.00,

which it has been impossible to classify, has been paid out on force account.

The capacity of this canal will range from 15,000 to 18,000 miners' inches—dependent somewhat upon the thoroughness with which the weaker points are protected.

The prime object of this enterprise is to furnish power for the smelting plant of the Parrot Company now being erected at Gaylord, and about 1,000 horse-power will be developed at this point.

A secondary object, however, has been the covering of the tableland for agricultural purposes, the land being owned very largely by friendly interests east of and adjacent to the company's plant.

The waters of the canal are led into the fore-bay 90 feet above the water in the tail race, and under this pressure three Victor turbines are being placed, each with a capacity of 500 horse-power, thus having one in reserve while developing a normal of 1,000 horse-power.

* * * * * * * * * *

I had hoped that I could include in this *résumé* a brief account of several other works of interest that have been in course of construction during the past year, but I have not succeeded in collecting the information desired.

Among the more important of these are the Castle Railway, the new Missouri River Dam at Canyon Ferry, and the new water-power plant for the Peck-Montana Company at Corbin.

It is probable that the society will be favored with a paper on at least one of these projects.

It has occurred to me that the one industry which has been carried to a most successful outcome in this state has never been noticed in the papers presented to the society. I refer to the milling and smelting of ores and the subsequent refining of the product.

Our membership includes men who have made a life study of the reduction of ores, and I merely suggest that the construction of the great reduction plants of the state have presented engineering features which should be made public, at least so far as the profession is concerned. It might be remarked that the Anaconda Company alone has expended a half million of dollars the past year in the improvement of its plant.

I wish here to acknowledge my indebtedness, for information furnished, to F. J. Taylor, Division Engineer, Northern Pacific Railway; J. C. Patterson, Engineer, Maintenance of Way, Great

Northern Railway; C. W. Goodale, of the Colorado Smelting and Mining Company, of Butte; Joseph H. Harper, civil engineer, of Butte, in charge of the Parrot Company's work at Gaylord (all of whom are members of the society); Mr. George E. Moulthrope, of Butte, and Mr. George S. Ames, of the Union Iron Works, of San Francisco.

* * * * * * * * * *

Now a few words as to the present condition of the society.

Some years ago I was one of a minority voting on the question of changing the name of the society by leaving out the word "Civil" and making it the "Montana Society of Engineers." I still think this would be a wise measure. We have in this country the American Society of Civil Engineers, which requires for full membership "the ability to design, as well as direct, engineering work." For a national society it is fit and proper to so limit membership, but in a local society, which admits members of the various engineering families, we should omit the word "Civil" in our title and welcome into our number all who are eligible under the provisions of our constitution. And yet, in the selection of our membership, there should be conservatism. If the object of our society is to promote the advancement of the engineering profession, its members should be representative men.

No matter what is a member's specialty—and all engineers of to-day, to be successful, must be specialists—he should be skillful. To make two blades of grass grow where but one grew before; to increase manufactured power, while simplifying the mechanism which produces power; to save time; to save labor—these are the province of the engineer, and in understanding the natural and physical laws which govern the universe he differs from the mere workman.

The writer, however, does not agree with those who would establish a wide line of demarcation between the engineer and the workman. "Let the engineers design the tools," they tell us, "and let the workman use them." To me there seems to be an absolute necessity in the knowledge of how tools are to be used and what is required of them before the designer gets to work.

I have seen and you have seen an engineer set right by a workman under him. It may have been humiliating, yet does it not show that there is something wrong in the preliminary training of the engineer? Why should not a manual training school be a proper adjunct to a school of engineering? Why should not a man who is to design great walls of masonry know how to use the tools of the mason?

It is this lack of practical knowledge on the part of engineers which so often antagonizes employers and the profession. The man who furnishes capital may admire your plans and elevations and sections, but if your knowledge is theoretical only, he will hire another to do his work.

To direct work you must understand the details of the work; you must know how to use the tools.

This is not a plea for "the rule of thumb." There is only one right way to do work. There can be no deviation from the rules prescribed by the physical laws of strength and power, but, to the knowledge of these laws, let the engineer add plain, every-day common sense. Let him learn the use of tools, and he will have less fault to find with the judgment of his employers and with the workmen who execute what his brain has planned.

To make a society like ours successful, there should be more interchange of opinion. Each member should consider it his duty to contribute information for the benefit of all. This obligation has been well expressed by Shunk in the preface to his admirable field book. "I take it," he says, "that the Father of mankind has not only made our minds to hunger for knowledge, as our bodies for food, but has also imposed upon us a kindly law of communion, by virtue whereof we cannot do otherwise, without violence to generous nature, than share with our fellows whatsoever we have learned that seems new and useful." Chaucer says of one of his heroes in the "Canterbury Tales" that he would gladly learn and gladly teach. This is the definition of the true scholar, and it should also apply to the members of this and similar societies. While we fall into a rut—become specialists, if you please—it is necessary for a liberally educated man to have a general knowledge. You must measure the work of others and let others measure your work. The society should be able to require from each member according to his ability and experience, and furnish to each member according to his needs.

And now, in retiring from the presidency of this society, the right may be accorded me of giving advice and of endeavoring to impress on the members present the one important duty we owe ourselves and our profession—the necessity of doing our work well. On this rests fame and all worldly success. Yet, surely, it is no exaggeration to say that no external advantage can be compared to the consciousness that the work that has been given us to do has been done as well as it was in our power to do it. If you want a solid foundation for your structure, go down to rock. Convince your employers that any other course is a mistake. If

a surveyor, let your closing error be so small you cannot plat it. There is always some one to check you up, some day, in some manner never dreamed of. It pays to do work well. In so doing it we make our profession the exponent of that philosophy which produces results, and which Macaulay calls the philosophy of fruit, "for it has increased the fertility of the soil; it has spanned great rivers and estuaries with bridges of form unknown to our fathers; it has lighted up the night with the splendors of the day; it has accelerated motion; it has annihilated distance; it has facilitated all despatch of business; it has enabled man to descend to the depths of the sea, to soar into the air, to penetrate into the recesses of the earth, to traverse the land on cars which whirl along without horses, and the ocean in ships which sail against the wind. It is a philosophy which never rests. A point which yesterday was invisible is its goal to-day and will be its starting point to-morrow."

INDUSTRIAL EDUCATION.

By Geo. W. Dickie, Member of the Technical Society of the Pacific Coast.

[Read before the Society, December 4, 1896.*]

When you invited me to address you on the subject of Industrial Education, I accepted readily, on the condition that I should be perfectly free to give you my own thoughts on this great question, not from the teachers' point of view nor from the humanitarian standpoint; but my desire, as far as I am able to clothe it in suitable language, is to give you my experience as to the kind of preparation necessary for a young person to undergo in order to fit him or her to fill an honorable place in the great industrial army.

It has not been a pleasure for me to prepare this address: in fact, there is no other subject that so completely accords with the saying of the wise man, that "he who increaseth knowledge increaseth sorrow," for the more one studies the conditions that prevail in the industrial world, the more of a tragedy human life appears to be.

When we consider the fact that the greater part of mankind labors under the constant and unavoidable necessity of providing itself with daily bread, and never loses an opportunity to loudly protest against the imposition, is it not sad that such a large proportion of men live by bread alone? And sadder still that so many live *for* bread alone.

Now, this is not the natural condition of mankind, for wherever industrial conditions have improved so that labor is not so exacting and life-destroying, and wherever intellectual and moral emotions are possible, bodily comforts, difficult as they are to obtain for the majority of mankind, seem small and mean as compared with the higher wants of man's nature, but the bodily wants must be actually enjoyed before these wants are felt. Food and clothes appear to be the greatest possible blessings to the hungry and the naked; but when once a good lining for the stomach and a warm covering for the back is secured, it is difficult to recall the deep cravings of the past, or even to exhibit the gratitude that we expected to feel at the possibility of food and clothing being ours.

I think we can, without any argument, take it as an established fact that the necessaries of life come to the great majority as a re-

*Manuscript received March 12, 1897.—Secretary, Ass'n of Eng. Socs.

sult of their labor in the production of these necessaries, or in the production of other useful and valuable things that can be exchanged for the things that are necessary for their life. That, I think, covers the whole field of industrial production. Every product of industry, therefore, represents so much labor, or rather, I would prefer to say, so much life expended, and if its value when produced will not procure as much life as has been expended in its production, the life expended in its production has been in a measure wasted. If, however, the thing produced will procure in the markets of the world more of the necessaries of life than were consumed in its production, by so much has the wealth of the producer increased. This is the reason why producers in a country where life is maintained on the consumption of only what is absolutely necessary can give their industrial product in exchange for so little as compared with a country where the maintenance of life demands, as necessary, a far greater range and quality of the results of industry.

Now, if it were simply a question of unaided human capacity for production, coupled with the actual necessities for the maintenance of the life of the producer in a condition suited to the work of production, the problem would not be at all complex.

But man has an intellectual and a moral side to his nature, as well as a physical side, and on that account his knowledge and experience is accumulative, and his wants increase with the development of the higher nature.

If we go back to the beginnings of his accumulations, we find him beginning the search for tools to help him in the struggle to maintain his life, learning little by little that all nature was but his instrument and making his first infantile efforts to employ her; making weapons of bone or flint to protect his life against his stronger enemies of the brute creation, for the possibility of life must come before its comforts, and we can trace this stream of human effort and experience down through the ages as it gathers force by the accumulations of generations of workers who have been able by their industry to do a little more than support their own life, and by so much have been able to enrich and expand the tide of human knowledge, and thus this stream has widened and deepened by all the surplus labors of the past, until in this nineteenth century of light and progress, we find this man who could barely maintain his own life in its early history wielding at will the phantom of steam and the lightning of electricity, compassing earth and sea by a power which his great co-worker, Nature, was laying up for him in deep store-houses securely locked until his

industry found the key, at the time when his naked foot first trod the earth he was destined to rule, and when he saw the necessity of making his knowledge and experience an ever-growing flood, to be enriched and added to by future generations, he found a way to do it by recording all the best of his knowledge in the imperishable symbols of language that have come down to us on this tide of human progress, which has grown so great and so complicated in its many tides that great masses of our race, instead of being carried safely on its bosom, are being engulfed in its mighty torrents.

So our inquiry to-night is how best to prepare the coming industrial army of men and women for the position they are to take in relation to this rising tide of human progress, for they must either be carried by it to better conditions or hopelessly swamped beneath its mighty flood.

What kind of education then, shall we provide for the youth whose comfort in life is to depend entirely upon their productive industry?

In this inquiry we will leave out those whose lot in life is to be amongst the army of unskilled labor; that army is divided into two great divisions. First, those who carry and fetch for the artisan, the hewers of wood, and drawers of water for the people, the shovel, and barrow, and hod men. Second, the class at the other end of the social beam, whose labor is entirely for their own amusement, and on that account is not productive industry; in fact, it is of all labor the most useless, and therefore comes naturally to men without being taught. The first of this class of unskilled labor is of great importance in most industries, and how the conditions that prevail in their life of toil could be improved, might form the subject of an interesting inquiry. Labor-saving machines of all kinds are lightening their burdens, but at the same time displacing them in vast numbers, so that the number that can be left in this class is fast diminishing, while the numbers of skilled workmen required is constantly increasing. So our inquiry as to how best to provide recruits for the industrial army is a highly important one.

This inquiry naturally divides itself into several questions, and these I will state and endeavor to answer just as they appear from my standpoint. Many of my hearers will not agree with me, because in many points my answers to these questions are directly opposed to the published views of many of our advanced teachers. They are also different from what I myself would like them to be.

On the question of trade education as a whole my experience does not at all agree with my idea of what such an education

should be, and this to me is the painful part of the subject. Were it the education of the children of well-to-do people alone that had to be considered, it would be a different question; but it is the children of the poor that complicates the question. Those children who must be utilized for a part of the family maintenance before any plan of industrial education can touch them.

This and other complications will claim our attention as we endeavor to solve the following questions:

1. What is an industrial education?

2. At what time of life should it be imparted, and how much of life is to be given for its acquisition?

3. In what way is this education to be acquired?

4. The difference between learning a trade and a technical education?

5. The present tendency of technical education and its effects on the industrial workers?

6. California industrially?

What is an industrial education? I would understand such an education to mean that the person who had received it attained to such a degree of manual dexterity in the production of some industrial article that would enable that person to compete successfully with others in the production of any article in the making of which such person is supposed to be dexterous. I do not think that anything less than this can be accepted as an education that will fit a man or woman to secure remunerative employment in any industrial establishment, the output of which must be at least equal both in quality and quantity to any other competing concern in the same industry. This fact appears to be lost sight of by those who have schemes that they desire to put in operation, which are to result in every graduate turned out by our great educational machine being a competent workman or workwoman in some of the many branches of industry, and this is to be done in such a pleasant way that the scholars will be skilled artisans without knowing anything of the painful process by which their fathers learned to work. In other words, it is claimed that boys and girls at school can be taught there, during the intervals of rest from mental studies, such trades as are practiced in the various industries of the country in which they live, so that when they leave school they can at once begin life as industrial producers.

At this point the teacher and the practical men at the head of our industries take different sides, for when the schoolmaster thinks that an industrial education has been given to the scholar, the manufacturer to whom the scholar applies for an opportunity to

put his skill into practice will not admit that his industrial education has even commenced.

The investigation into the merits of each side, which might be termed the school side and the shop side, leads us to the second question in our inquiry: At what time of life should this industrial education be imparted, and how much of life is to be given to its acquisition?

This question is very complicated, and in order that you may not misunderstand me in the remarks I am to make, I must again say that I am looking at this question as it affects the children of working people, whose industrial education is to be the instrument whereby they are to procure the means of living. If this instrument works successfully, they will live and may be happy; if not, they will starve and die. "Then," says the schoolmaster, "teach the children trades in the schools, so that when they graduate they will at once become money-earning factors in the family."

I will agree with the schoolmaster in this, that the industrial education should begin early in life; that teaching dexterity of the hand in certain directions should be co-incident with the development of the mental faculties. But as the school days of working people's children are necessarily very short, owing to the stern fact that physical growth needs bread, the schoolmaster is forced to decide what he shall teach in the five or six years of child-life that is entrusted to him.

I think you will all agree with me that the intellectual faculties must be awakened early in life if that life is to experience any of the joy that springs from mental emotions; besides, even in the practice of industry, the man must have learned the use and meaning of the symbols that express his own language. He must also be able to express his own thoughts in these symbols; he must also know all the symbols by which quantities and values are expressed, and be able to readily grasp their various and more simple combinations. In other words, he must be able to read, write, and compute, and this much education must be imparted, even should the knowledge of any industry in the school days be thereby rendered impossible. In some children the mental faculties awake slowly. We get many boys from the public schools to learn the various trades in our establishment, and it is astonishing how few of these, after being at school from five to six years, can read clearly, write correctly, or compute beyond the most rudimentary stage. This shows that these absolutely-necessary rudiments of education are hardly now acquired by the children of working people during their short school life. Now, unless the state is to support the

scholar as well as the school, the school term for these children cannot be extended, and we are forced to the conclusion that education in the arts and industries must be continued into the bread-earning period of their lives.

Still I will admit, in fact I think it highly necessary, that industrial lessons should be given in connection with their mental studies, and I am further sure that such lessons would be a great stimulus to the mental faculties.

And this leads to our third question: In what way is this education to be acquired?

We have noticed that there are certain items of instruction that must be imparted at the school or they never will be acquired at all; but while these are being instilled into the young mind, the scholar can be at the same time introduced into the field of industry. The text books might consist largely of industrial history and biography. Object lessons on practical industry could be presented in such a way to him that he could follow industrial processes, and the kind of work that he felt the greatest pleasure in observing would be an indication to the teacher as to the direction his studies should take.

With the gradual extinction of small industries conducted by the workers therein themselves, and the rise of great industrial concerns, employing thousands of people within great buildings closed to all except those who work therein, and open to them only in the one department in which they labor, the children of our time have lost what was a mighty moulding factor in the lives of our fathers. I never realized how much I owe to the fact that all my spare time when at school was spent in my father's workshops until my own boys were growing up around me without any such opportunities.

The subdivision of labor, while it is a great economical factor in the cost of production, has a terribly dwarfing effect on the minds of the producers, and the education of the young people should be directed to giving them broad comprehensive views of the scope of the industry in which their lives are to be spent.

The school should not aim to produce skilled workers in the production of some single piece, that multiply it as you may, never fills the mind of the producer with the sense that he has produced any complete thing of usefulness or value to his fellowmen. Skill in piece-work will be imparted soon enough by those who are to profit by it. Teach the boy at school all the past history of the industry he is to work in; place at his disposal that vast heritage of experience that his fathers have accumulated for the use of the

coming generation of workers. This the schoolmaster can do, and do successfully, and when that is done the young people will come into our industries with higher aims than they do now, and their hearts will be more in their work, for they will then be able to understand what is the part they perform in the completed product in which they labor.

Here I think it might be appropriate for me to say the one thing I never miss the opportunity of saying when my subject leads to it, and it is this: That in connection with the industrial education of the working youth of our State, we ought to establish in the metropolis of the State an industrial museum, where all our natural products and the processes by which they can be converted into marketable articles would be exhibited in their proper sequence, and illustrative of their historical development.

Th City of Philadelphia has set aside thirty acres of land in the heart of that great industrial center for museums of art, of science, and commerce, and has also voted a large sum of money to begin the work.

The State of Pennsylvania has also voted money toward the object of these great educational enterprises.

To my mind the Industrial Museum of Edinburgh, representing the industries of Scotland, is the greatest educational institution in Europe to-day, instructing by observation those who have neither time nor opportunity to study through books the history and processes of an industry.

Here the raw material, for instance a specimen of iron ore, is shown, going through all the manipulations that transform it into the many articles of value in which we find iron in the metal markets of the world, and with the new value that each process gives it distinctly marked, so that the student can see the effect of labor in creating these values. Or a bunch of flax stalks is shown at one end of a table with its value marked, and the student of textiles can follow it through all the manipulations of steeping, stripping, heckeling, drawing, spreading, roving, spinning, bleaching, winding, weaving, calendering, etc., until he reaches the finest cambric, with the new value that labor has imparted shown at each stage.

We need an institution like this to bring the wealth of the world's industrial experience within the grasp of the coming generation, for the sum of human experience has become too great to teach by any other method. The school time for the great bulk of workers cannot be lengthened, though the sum of knowledge has increased, so the slower methods of teaching must give place to practical demonstrations that can be grasped in blocks, as it were.

Otherwise, the tide that a man could ford a generation ago would engulf us now should we attempt the old fords.

Now I think you are prepared to hear me say that I do not think that schools should attempt to teach a trade. We cannot dispense with the great rudimentary beginnings of knowledge that every child must receive, and with it a general knowledge of any industry that suits the scholar, can and ought to be imparted. But to learn a trade, all the commercial elements that surround that trade must be learned with ability to handle the tools of production. This kind of instruction, in my opinion, can be acquired in one way only, and that is by serving a regular apprenticeship in an industrial establishment, where the product must meet competition in the market. Here the youth not only learns to use his hands to the best advantage, but what is of more lasting importance, the quality of endurance. His place, though at first it may be a very small one, must never be vacant. He is expected to be there when the whistle blows in the morning and remain there until it blows at night, and on every working day in the year; otherwise the work would be disorganized. So the sense of responsibility and devotion to duty is acquired, along with the ability to produce work in a commercial sense.

These qualities can never be acquired at any trade school; there the ability to do a thing is all that is possible, but to do it commercially has never been thought of.

Some time ago a prominent professor in a technical school showed to me a piece of work done by a young man at school, aged nineteen. It was a bar of steel one and one-quarter inches square, about nine inches long, squared on each face and on the ends, and having a key-hole through one end and a taper-pin hole through the other end. Now, this was not a part of any specific machine, it was simply an exercise in the handling of tools. I asked the professor how quickly the young man got through with this piece of work. "This," said he, "was the exercise for the term of twelve weeks," and he pointed out how well the work had been done. "But," said I, "professor, there is one very important matter that you forgot about in your satisfaction at the result of this young man's labor, and that is the commercial element. This piece of work he has exercised on for three months is worth for labor just $1.75, and would be produced in the shop by any young man of his age in about four hours.

Now there is no particular harm in this kind of thing being done simply as a school exercise, provided it is not considered as learning a trade, and provided that the time thus occupied is not

13

being deducted from the bread-earning portion of the young man's life.

The boy or girl who is to live by working in any industrial trade should begin their bread-earning work not older than sixteen. If before then they have learned anything of the trade they are to follow, it should be in the direction of general knowledge of the scope of that trade and its relation to the industries of the country. The narrower and more personal matter of being able to earn a living therein, will be best acquired in working out the daily tasks of the workshop, and at twenty-one that young person should be able to hold his own in competition with other producers, and should be able to earn what a day's labor is worth in that trade.

This leads us to the fourth question of our inquiry: The difference between learning a trade and a technical education.

It would be a grand thing if every working man could have a technical education, so that the qualities and chemical constituents, with a knowledge of all the manipulations through which all the material he handles goes to prepare it for use, would be familiar to him. If he were able to understand all the co-relations of the things and the forces that come into play in the trade at which he works, he would no doubt be more of a man than he generally is; but the attainment of such knowledge, owing to the necessities of daily bread, if it comes to him at all, must come through his own efforts and at the sacrifice of his leisure hours to his thirst for knowledge.

That such a knowledge is possible for working men is proved by the fact that so many obtain it in this way, and is valued and cherished just in proportion to what it has cost.

Technical education differs from a trade education in that the latter is the education of the hand to be dexterous in production, and the head in the necessary knowledge to guide the hand; while the former is the education of the mind to solve problems, to experiment with the qualities of materials, to measure and direct forces and teach the hand and eye, the conning art of design.

A technical education cannot be acquired in the workshop; such an education means technical schools, especially designed to meet the requirements of the people; in fact, the scientific courses and engineering courses at our universities to a large extent meet the requirements of the technical student; but to make it possible for the young man learning a trade in any of our workshops to acquire a technical education that would enable him to aim at the highest position in that trade, technical schools should be in ses-

sion when he is not at work, so that he may have all the helps possible in his struggle to reach the goal, and these should be within easy reach of his living quarters, so that he would not lose time by the way.

Hence schools or colleges for instruction in the arts and sciences relating to trades by which the people live should be located in the centers of these trades, so that the education they offer will be within easy reach of the workers. For the fact must never be lost sight of that the great bulk of the young people must work in order to live.

I had many a discussion with the late Senator Stanford on this point, he saying that his aim was to make a scientific education possible to every workingman's son. Then I would tell him that his proposed institution of learning must be planted next door to the workshop and must be run when the shop stops, otherwise workingmen's sons would never get to his university.

Workingmen, if they have sons at all, are apt to have five or six of them, and it is fortunate that it is so, otherwise our industries would stop for want of men. But suppose a workingman with, say five sons, all desiring to go to the Stanford University. The very least it costs to keep a young man there is $30 per month; and suppose the gross earnings of the father is $75 per month, which is above that of the average tradesman. It needs no figuring to show the impossibility of his sons' going to Stanford, unless they are of the stuff that sometimes forces itself through a university without funds. But the university can only stand this as an exception to the rule. So the great university that Stanford has founded to benefit the sons of workingmen is filled with students largely from other States whose parents are able to keep them at a university.

The British method of polytechnic schools scattered amongst the great industrial centers, each adapted to the requirements of the particular trades of the district, where the instruction is largely by lectures and museums of industry, comes nearest to meeting the wants of the workingmen, and they have been a great elevating power wherever they have been established.

The development of technical education during the past ten or fifteen years has been one of the marked features in the progress of general education. Vast numbers of young men are graduating yearly from our universities and scientific schools. Some with a little knowledge of how to use tools, but the majority with a purely technical education. These men expect to obtain places in industrial establishments. Many of them have influence through friends

to make openings for their admission, and in time turn out to be bright and able men. Few of them care to go into the shops and learn to work, their ambition being to get charge of departments or engage in designing.

Those who do go into the shops, thereby gaining a practical experience in actual work, combined with the technical education acquired in the schools, are the men we are likely to find at the heads of future industrial establishments. This class of men are a new element in the industrial field of labor, the full effect of which is not yet felt. Its tendency, however, is to create classes in the ranks of industry.

The apprentice boy whose parents require his help as soon as he has acquired the physical strength to give it, to provide the family daily bread, finds between him and the places that used to be the ambition of the best boys to reach, an army of university graduates, who could not do the work he is now doing, but who are well equipped with the kind of knowledge that he lacks in order to fit him for the place he aspires to. The mathematical problems that he struggles with so laboriously in his lesson hours, that come so slowly to his untrained brain, are but simple equations to the university man. So he sees the places of trust and honor filled up before he is able to fit himself in such a way as will command recognition; so he loses heart and hope, gives up the fight, and sinks back to his position at the bench, where he remains, a more discontented worker, because a disappointed one.

Of course the great bulk of men in the industrial army must be privates, no matter what kind of education may be given to them. The great tendency, however, at present is to officer this army, not from the best soldiers in the ranks, but to have a distinct class specially trained for officers. This is the inevitable result of technical education. Those who can afford to thus train their young people usually have some influence by which they are able to place them in the staff of some industrial concern, and thus open the way for their future progress if they have any ability.

What our public benefactors ought to aim at is to place within the reach of the boy who must work for bread the best means possible for him to acquire the technical knowledge for a thorough mastery of his own trade in all its details. Such means must be brought to the boy, as his time is very limited, and degrees of proficiency should be conferred upon successful students, so that the evidence of their progress would be manifest to those who have the power to place them in the positions for which they have worked so hard to fit themselves.

It might be inferred from what I have said that I am opposed to university graduates coming into our industrial establishments and filling the best positions, but such is not the case. I am only pointing out the tendency to a dividing up of our industrial army into classes where the chance to pass from the ranks into positions of command is thereby rendered very difficult, if not impossible.

The aspiring youth who is barred by necessity of providing himself with daily bread from obtaining that technical knowledge necessary to a complete mastery of his trade, should be given all the chance that his spare time will permit him to utilize, that he may at least have a fighting chance to win. It is so hard to work for bread and struggle for knowledge at the same time, and so sad that the great majority must do it or be worsted in the fight.

I have endeavored to present to you my views on this great subject from my own point of observation. I am in close touch with its practical side, and am greatly interested in watching every movement made to try and help working people to a higher education.

I have tried to avoid the darker sides of this many-sided problem, touching only on what might be termed the higher branches of industrial education.

There are many branches of industry where children are put to work, because in them the child has a greater money-earning value for the time, and bread is the one thing most to be desired in the homes to which they belong.

Our rivet-heating boys come to us at about twelve years of age, and they can earn about twice as much as a boy of sixteen as an apprentice mechanic. What can a boy of twelve have acquired of any kind of education at school? Yet any scheme that proposes to provide for him any kind of education, industrial or technical, must not only teach him, but feed and clothe him as well.

It appears to me that most of our efforts after better industrial and technical education is in the direction of helping the strong and well-to-do, and never touches the weak, the poor, and the helpless mass of humanity that need help so much.

This is not a fault of those good men and women that have the desire to help those who need it most, but it is the inevitable result of social conditions that prevail among us. So long as poor working people are depended upon to maintain and increase the population, and they are willing to accept this duty, too often evaded by those who are better off, and so long as the poor parent must feed and clothe his child, that child will be utilized for bread earning instead of being taught to solve the problems of life.

In this matter of education for the poor, it is a condition and not a theory that confronts us, and this condition I think will continue so long as our present social fabric stands.

I am afraid that my efforts to express in words what my thoughts are on the questions we have been considering is anything but a success. I only hope that I may not be misunderstood, and that there is in the future some grand plan that will help to make it easier for the child whose parents are forced by poverty to eat the life of their child.

You will permit me now a few words in conclusion on California industrially.

For some time past the industries of California have been subjected to an endurance test, which has resulted in some of them being crushed out of existence. This fate may seem cruel, hard, and unjust to those who are thus deprived of the kind of work for which they are especially fitted by nature and education; but it is the law of industries the world over, and California is no exception.

Yet, notwithstanding the disappointing results that have followed the introduction of certain industries in this fair land of ours, there remain many fields of industry well adapted to the conditions of California life, on which as yet no cultivating hand has been laid.

What magnificent possibilities are yet latent in that greatest of all our industries, where the reward of the honest and skillful worker comes from the bountiful bosom of Mother Earth. The key to this rich store-house lies in the development of transportation facilities. When that key shall open a passageway for the transportation of commerce through the attenuated waist of this continent, hungry Europe will be fed from the fruitful valleys of California. When that time comes the epicures of the old world will eat of the fruit of our vineyards and orchards kept fresh in the dry cold air of a special fruit compartment on the quick dispatch steamers of the California and European line, via the canal. South America and Africa will become contributors to our welfare when we establish direct steamship lines to these lands, and as these and other doors of commerce open to our natural products, our engineers will multiply these products, for they will construct great works to store the water of our mountains and train it to turn the busy wheels of industry on its way down to slake the thirsty lands of the valleys, until this wonderful land will have more food to export as the consumers at home increase.

The more we learn of the natural resources of California the

less we need fear for the industrial outlook. We have everything necessary for the building up of a great industrial commonwealth on the western edge of the United States.

Yet, notwithstanding the bright picture that can be presented of our future prospects, we must not forget that some of the most favorable lands as to natural resources have cut no figure in the industries of the world.

In the development of great industries, men and women are of more importance than things. Hitherto we have lacked in California that unity of aim and effort that is the chief characteristic of a progressive people. Our representative men controlling the various interests of the State are all more or less influenced by the peculiar methods of the countries whence they came, and the building up of the individual has been attended to, and that often to the disadvantage of the State, and even of the particular industry in which the individual is engaged.

This, I trust, will in part disappear as a new generation arises to shape the destinies of the State. California's future is very much in the hands of the young generation that is beginning to put its impress on the work we are now doing.

If our young men are well trained in the habits of industry, and our young women in the practice of thrift, if they come into our industries with a noble purpose, ready to give rather than to get, our future is safe.

It pains me to hear young men discussing what they can make out of the work they propose to engage in. No industry will ever be the better for what we are to get out of it. It is what we are going to put into the industry we have chosen to work for that is to build it up and make it strong and enduring.

If we are ready to put ourselves, that is the best of our life and thought, into our industries, we need not fear for the future. We, whose heads have whitened in the struggle to estalish industries in this land of our adoption, expect grander service from the youth for the land of their birth.

The young man of to-day as he stands on the threshold of his active industrial life must be equipped to meet the competition of the world. The advantage of distance from the competing centers of industry that used to help us in California are fast disappearing, and he must enter the fight trusting in his industry and skill alone. He must gather all the experience from the past history of his own industry that his competitor has. He must know all that has been accomplished in the past history of the industry by which he expects to live. And that vast heritage of experience that has been

accumulated by the labors of the past should be placed within his reach in the shape that he can most readily comprehend.

My friends, is the California industrial bark to be carried on this mighty tide of human progress to a bright and glorious future of prosperity, or is it to be swamped in its deep tides? I cannot tell you. The personnel of the crew will decide that question.

DISCUSSION.

The discussion of above subject at the December meeting was continued at the January, 1897, meeting. The paper was by request of members re-read by its author, Mr. Dickie. The following is the discussion:

Prof. Marx, of the Stanford University.—Mr. President, I do not feel competent to discuss all the points presented in this valuable paper, but I think I can throw a little light on one or two of them.

There is a great deal of difficulty of giving poor people the higher technical education. The movement of university extension has proved that. A few years ago in Wisconsin an attempt was made not merely to extend the ordinary courses of university extension into the outlying towns, but also to introduce a line of technical education. I was at that time commissioned by President Chamberlain, of the Wisconsin University, to go into some of the industrial centers of Wisconsin and interview the manufacturers and foremen of large factories, in order to see what could be done in that direction. The result was extremely discouraging. As Mr. Dickie stated in his paper, boys go into the factory at twelve years of age up to sixteen and twenty, and they commence at seven o'clock in the morning and work until six o'clock at night. Now, every human being has only a certain amount of vitality and energy to expend. It may be expended in two directions, in doing this certain amount of labor and in learning a trade, or it may be spent in part acquiring the technical knowledge which Mr. Dickie admits is very desirable. But when a boy or young man has worked hard for ten hours of the day, there are comparatively but a small number who are willing to enter a school, or to take a special course at a time outside the hours of their daily toil, to get this supplementary training so absolutely essential to their progress. I made a great effort in one town, which has a large laboring element, to establish a class, and found it absolutely impossible to get a sufficient number of men to form one. It seems to me that if we are to establish such schools, assistance must come from the side of the manufacturers. But there, again, I met with considerable

discouragement. I suggested to them to let the men leave the shop two hours earlier, but they were not willing to do that. They said they had to keep the machinery running, and that every man must be in his place. So the result was that I met with no encouragement whatever, and I went home a good deal discouraged.

Mr. Dickie deprecates the fact that young men who are not able to go to the trade schools are placed in the shops and are kept to work at one thing, and are thus confined to narrow ideas of work. The condition of our industries at the present time is such that there is but very little opportunity for young men to develop their abilities; it is to the interest of the manufacturer to give a young man one piece of work, and keep him at it. As it is not for their particular interest to develop that young man, they will not do it. Unfortunately the number is not very large whose humanitarian interest is greater than their financial interest. We see this difficulty of which Mr. Dickie speaks, and, of course, we all feel sorry that it exists. But I do not think the solution which he has hinted at is one which will solve the problem.

I would state this before concluding: Trade schools and museums, such as Mr. Dickie has spoken of, exist in foreign countries. They have been established in all the industrial centers of France and those who have had the benefit of them have developed into good workmen. I believe the industries of France have advanced since their establishment. And such is the case with Germany. There it is made compulsory by law that manufacturers shall send their apprentices to these schools. Nothing of this kind exists in this country that I am aware of.

Mr. Dickie. It is the possibility of having something of the kind in this country that I am hoping for.

Prof. Wing, of Stanford University.—I have another solution for this question. I think the problem presented is partly a social problem and partly an industrial problem.

New England has been the center, and still is, of the industries of this country. I was employed in a shop in New England for some time at different periods, and I was very much interested in studying the industrial conditions there. What seemed strange to me was, that in structural iron work, for instance, the iron and the coal could be shipped from Pennsylvania into New England, and the iron could be worked up and could be shipped back to Pittsburg, to Chicago, and to the Anaconda mines, and compete with Pittsburg manufacturers. I think the reason was because they have better workmen in New England than in any other section of the United States. Being a great center of industry, and all

the towns of importance being engaged in manufacture, men are more constantly employed. When they are thrown out of employment they go out on the farms and obtain some income from this kind of labor. Some of them own land which they till. I was connected with a shop where a great many workmen drove in five or six miles with their own conveyances, and the manufacturers had a long shed built in which to put them. Suppose the workmen had five or six sons; during their early training they are employed in what I consider one of the best schools of manual industry, and that is work on a farm. In this way there is a certain amount of support for the family, and at the same time a good physical training, some experience in the handling of tools, and the development of the habits of thrift and industry. When they get older, and wish a high-school education, they can go to a neighboring town and get it; if they wish an industrial education, here is a town five or six miles in this direction where there is a certain manufacturing line they can study, or they can go in another direction to a town where there is another industry, and they can choose such as their ability and inclination adapt them to. Under such conditions they make good workmen. It is schooling of the best kind, and much better, I think, than any museum could be.

It seems to me that the only solution of our industrial problem in California is along these lines. Of course we lack the valley settlers. But as spoken of in the paper we have our mountain streams which can be developed into power for great industrial manufacturing plants, and we can locate them in one of the most fertile sections of the United States; and I believe that the workmen in the shops can have their own homes and their own land, and if out of employment in the mills, they can keep themselves busy. If it be desirable to have education of a technical nature in connection with those centers, it is certainly possible.

Take it around Hartford, Connecticut, itself a manufacturing city, there are a number of manufacturing towns, New Britain, Middletown, Meriden, Willimantic, and still farther away, Waterbury, and a number of other places, all easy to be reached by workmen and with abundance of farming lands about them. These make excellent conditions. To see that the surrounding conditions of the workmen are favorable is one method of solving the industrial problem. While visiting works in Philadelphia in the line of structural iron manufacture, I could not help contrasting the surrounding conditions with those of New England. All the land in that section was taken

up for building purposes or city lots. As I approached the works the first man I saw was a policeman, and no one could approach the establishment without a permit from the office. They are having continual difficulty with their workmen. In the manufacturing towns of Connecticut such a thing as a labor strike is almost unknown. Many of the workmen own their homes. I know an instance of a man who had been a piece-work contractor in a manufacturing establishment which had several branch establishments scattered throughout Connecticut. In the course of time it was found necessary to concentrate the manufacturing into one large concern. This man had his home and did not wish to leave it. He immediately gave up his work that he had been accustomed to, and went to work in a neighboring shop as a day laborer at three dollars a day. He had a comfortable home in a little village, and he was one of the selectmen of the town, which office corresponds to our supervisors here. That man did not consider it as beneath him to go into a shop as a common laborer. He gave his son a college education. I do not believe that it is impossible for a workman earning seventy-five dollars a month to give his children a good education, if he practices economy and thrift, owns his own home, and is careful in his living expenses. I believe that our manufactures here can be located in sections of the country where the industrial conditions will be such that the workmen can live and be respectable.

PROF. SOULE, of the University of California.—Mr. President, I have been very much impressed by your paper. I think there is a vast amount of truth in it. I could not attempt to discuss this matter thoroughly without preparation, and from the few moments I have listened to the arguments. I will only make a few remarks upon some of the points that have been brought out.

First, in regard to the children of poor parents, if it were known beforehand that the children would only be allowed to take the primary course in the schools and would then have to go out immediately and earn their living, much more might be accomplished to fit and benefit the child while engaged in its studies in the primary school. Speaking more particularly about our own State, I think there is a vast amount of "stuff" (and I use the word deliberately) attempted to be forced down the mental throats of the children in the primary schools. A vast amount is taught to them in a very imperfect way which does them no good, and which, instead of stimulating their interest and observation, tends to dwarf their intellects.

For such children as I have mentioned there should be a

course that is somewhat limited, as compared to that given to them now, but which would suffice for all their needs. Such a course should embrace arithmetic, grammar, and geography, and they should be taught to read readily and well, to spell correctly, and to write plainly. In arithmetic there should be omitted such matters as banking, exchange, compound proportion, and the like, and they should be taught only the simple mathematical principles, common and decimal fractions, ratios, and simple proportion, and what is sometimes called analysis. That is all that would be required, and with a good teacher it would take but comparatively a short time to teach these branches thoroughly. If instruction were limited to these few subjects, and each subject limited to its proper field and sphere, a great deal of time would be saved. The teacher should be thorough, and one who would stimulate the thought of the child, and lead it on to think and observe for itself.

At the same time, and in the same course, having saved so much valuable time by omitting all these superfluous subjects and ridiculous divisions of these subjects, they might then receive the beginnings of their industrial education.

But the result of the present system is that these poor little creatures are overwhelmed with subjects that they can only learn a little about and which they forget within two months after they leave school, and which are of no practical benefit to them. Instead of teaching them what is useless, let them commence to learn the elements of a handicraft, and the elements of the industrial work in which they are to engage. This, of course, could not be carried very far, but what they did acquire in this direction would be of direct practical benefit in making a living and making progress in the world.

It is very important to have good teachers in the primary schools—natural teachers. I think they occupy as important a position in the educational world as a teacher in a university, and even more so, because the teacher in the primary school is forming in the minds of the pupils the proper or improper way of approaching every subject of investigation. The mere make-shift teacher will adopt make-shift methods and will introduce in the minds of the pupils a make-shift system, and the education will be wrong from the start.

As far as I know, I agree with Prof. Marx, that the attempt to give a good thorough technical education to young men or young women who have had to work hard through the day is a failure. The powers of mind and body are practically exhausted by the day's work. I know of no instance in which that attempt

has succeeded except in the case of a few bright minds that exist in every generation and in every class, who will work their way to the top in spite of all obstacles; they will do it with any system. So it seems to me that the idea of giving instruction after the day's work is finished cannot be carried out successfully. But I do think that in our public schools a reasonable amount of time could be profitably used to the work of the arts and handicraft, not so much with the intention of making experts, as by cultivating the mind of the young person in those directions. A boy who has learned by successive trials to cut accurately a square hole through a quarter-inch plate of iron has really gained a great deal. He has learned how to be accurate, and what is good workmanship. These ideas firmly fixed in his mind, will be invaluable to him in his life's work. The value, of course, is not so much in the thing itself that is done, but it is in the reactionary effect, in the habits formed, and in the discipline received in the operation.

With regard to a thorough technical education in the technical schools, in this hurly-burly world of ours, I do not think it is practical or possible within the time that the poorer classes have to acquire both a technical and practical education, although I admit it is desirable. But it seems to me the student by means of the workshop, in connection with the technical school, can at least acquire sufficient knowledge to enable him to judge of good and poor work, to have some idea of what is required to be an expert workman, a good designer, an inventor, or an engineer.

But after all, Mr. President, I am sorry to say that Nature is pretty severe and hard on us. If we violate her laws, either knowingly or unknowingly, the punishment is equally severe. Such is her course that the weakest will have to go to the wall. It is so in the brute creation, and it is so with humanity. It will always be the case, as in the past, that the poorest and the weakest will have the hardest lot in life and will have to occupy the lower place in the social scale. It seems to me that the best we can do in the matter of industrial education is to give everyone a fair chance. The better element will rise; the others will have to take the station in life which Nature and their own lack of ability forces upon them.

Prof. Buchanan closed the discussion by reading a portion of an article he had written touching upon the utility in education and the necessity of technical schools from the standpoint of the humanitarian and the educator.

EARLY HISTORY OF INSTRUMENTS AND THE ART OF OBSERVING IN ASTRONOMY AND CIVIL ENGINEERING.

By Charles S. Howe, Retiring President of the Civil Engineers' Club of Cleveland.

[Read before the Club at the Annual Meeting, March 9, 1897.*]

The methods of observing in astronomy and civil engineering are essentially the same; the instruments of geodesy, which is one branch of civil engineering, are of the same character as those of practical astronomy. The latter treats of the exact location of the heavenly bodies, while the former treats of the exact location of points on the earth. As these two sciences are so nearly related, a history of instruments and the art of observing in one must be very much the same as in the other. Astronomy is undoubtedly the older of the two, and, as more attention has been given to scientific observing in this, I shall bestow more time upon it than upon the other. Civil engineering, in its simple form of surveying, was invented to subdivide land after the annual overflow of the Nile in Egypt. The Chinese claim to be the fathers of astronomy, but we know very little about the early history of their methods or their instruments. Astronomy, as we know it, came from the Chaldeans. Shepherds, watching their flocks by night, soon became familiar with the principal stars and observed the simplest phenomena. Having no clocks, the heavens became their time-piece; having no calendars, the movements of the sun and moon marked the divisions of months and years. One fact very soon became apparent, namely, that while the great mass of stars were seemingly at rest with respect to each other, certain celestial bodies were in motion. Thus the moon moved so rapidly among the stars that a few hours' watching was sufficient to detect its motion. Continued observation showed that it passed from new moon to new moon in about thirty days, and so the length of the month was established. Next, the apparent motion of the sun among the stars was observed and its period placed at about 365 days. Then it was seen that certain of the stars themselves were in motion, sometimes forward, sometimes backward, but in the end completing the entire circuit of the heavens. These were called wandering stars or planets. We do not know when these observations were first

*Manuscript received March 25, 1897.—Secretary, Ass'n of Eng. Socs.

made. No instruments were used and no records kept. The Chaldeans also observed eclipses, noting the time to the nearest hour, and the magnitude of the obscured part of the sun or moon.

Herodotus tells us that the Greeks obtained from the Babylonians a knowledge of the pole, the gnomon, and the division of the day into twelve equal parts. The pole was a concave hemispherical sun-dial having a vertical rod in the center by which the interval between sunrise and sunset was divided into twelve equal parts. This instrument shows a knowledge of the uniform motion of the celestial sphere, but does not indicate any deeper knowledge. The gnomon was a very simple sun dial by which the altitude and position of the sun were determined. The length of the solar year was approximately measured by means of it. When the shadow cast by the gnomon was the shortest it was the summer solstice, and when it was longest it was the winter solstice. Half way between these times were the equinoxes. Thus we see that these ancient astronomers observed those facts which were most apparent, but did not reason deeply upon their results.

The first observation recorded by the Greeks was a determination of the summer solstice by Meton, in 430 B. C. He used an instrument called the heliometer, which was probably one form of gnomon. When Alexandria became the capital of the civilized world, a great university was built. Scholars came from all nations to teach or study. The sciences were cultivated, and among them astronomy held a high place. A large observatory was erected, fitted up with circular instruments for determining the positions of the heavenly bodies. Here Eratosthenes obtained the declinations of stars and the obliquity of the ecliptic. This could not be done without instruments, but our knowledge of them is very slight. Ptolemy speaks of an instrument having two concentric circles turning on an axis. The inner one had two small prisms, and when the shadow of one prism fell on the other an index arm showed the altitude of the sun on the outer circle. These observations were made at the summer and winter solstices, and the difference between them gave twice the obliquity of the ecliptic. This Eratosthenes found to be eleven-eighty-thirds of the circumference of a circle, or 23°, 51′, 19.5″, which agrees very closely with its true value at that time. To find the time of the equinoxes, a ring was placed in the plane of the equator; when the shadow of the upper part fell upon the middle of the lower part the sun was in the equator. But Eratosthenes did not confine himself to measurements in the heavens, he measured the length of a degree on the surface of the earth by the same method in use at the

present time. His two stations were Alexandria and Syene, in Egypt. On the longest day in summer he noticed that there was no shadow at the bottom of a well at Syene, while at Alexandria the shadow was 7° 12′ in length. This gave the difference in latitude, but he obtained a poor result for the length of a degree, which he gives as 79 miles, because of a mistake in measuring the distance between the two stations.

Many facts can be ascertained by observations made at one time or by the work of one observer extending over several years, but the great fundamental data upon which geodesy and astronomy rest must be determined by comparing observations made at widely different periods. Hipparchus, who lived about 130 B. C., seems to have been the first of the ancient astronomers to use proper methods of calculations based upon observation. Up to this time it had been supposed that the length of the tropical year was 365¼ days. By comparing his observations with those made by Aristarchus, 147 years earlier, he found the tropical year to be 365 d., 5 h., 55 m., 12 sec. This is not an exact result, as it differs by about 6 m. from the true value, but considering the imperfect instruments then in use, it is a great advance over previous knowledge. It marks an epoch in calculation. He was also able to prove the eccentricity of the earth's orbit by noticing that the interval from vernal equinox to autumnal equinox was not the same as from autumnal equinox to the next vernal equinox. Hipparchus is supposed to have invented the astrolabe, an instrument having three circles, one in the plane of the equator or ecliptic, another in the meridian, and a third at right angles to this. An index arm moved on the equatorial circle, and by this the distance between two bodies near the equator or the ecliptic could be determined. Up to the time of Ptolemy all instruments were made circular. The latter, who lived about 150 A. D., used a quadrant for his observations. He preferred this form on account of the size of the apparatus. By the crude methods then employed it was difficult to divide the measuring arc accurately, and the divisions must not be so small that they could not be seen with the naked eye. A circle 10 feet in diameter and divided to degrees would give one inch to each degree, or one-sixth of an inch to each 10 m. When the shadows of pins or prisms were used to indicate the position of the sun, observations nearer than 10′ could not be made even with an instrument 10 feet in diameter. To make the instrument smaller a quadrant was used. But this was evidently a backward step. A quadrant cannot be divided as accurately as a circle, because there are not the same opportuni-

ties to correct the divisions. Two points can be found 180° apart on a circle by turning the circle half way around and again observing; or a circle can be divided into four equal divisions by placing two sights in such a position that the distance between them spaces four times around the circumference. This method could be readily applied to the rude instruments of Hipparchus' time, but could not be used on a quadrant. Ptolemy made his quadrant vertical by a plumb line, but he does not tell us how he fixed it in the meridian.

There were no accurate methods of measuring time. Some forms of water clocks were used when the sun was not shining, and at night the part of the zodiac on the meridian was noted. The Arabians made larger and better instruments than the Greeks, but did not make any great improvement in methods of observing. They determined time by the altitude of a known star, and fixed the meridian by equal altitudes of the sun east and west.

For many centuries after the time of Ptolemy work in astronomy and geodesy nearly ceased. We read of observations at Bagdad in the 13th century, and of some work among the Moors, but no radical advance was made in modes of observation. At the revival of learning in Europe interest in astronomy was awakened, especially in Germany. The voyages of discovery which were made in the 16th century necessitated a good knowledge of the heavenly bodies.

Regiomontanus, about the year 1475 and later, wrote ephemerides of the sun and planets, which were used by Columbus, Vasco de Gama, and others. This demand developed the study of astronomy in the German universities. Instruments and methods were much the same as in the time of Ptolemy. Waltherus, of Nuremburg, found the place of planets by observing altitudes and distances from two fixed stars. The idea of locating a heavenly body or a point on the earth by means of a clock had not yet been developed.

Clocks came from eastern countries originally. Pacificus, of Vienna, in the 9th century, constructed a clock with wheels. They soon became quite common, but could not be used for scientific purposes. They had balance wheels for regulation and would show the interval from noon to noon with considerable accuracy, but intermediate intervals were not marked with uniformity.

Galileo discovered that the beats of a pendulum were nearly isochronous, and tried to apply the pendulum to clocks. His efforts were not very successful, but Huyghens, in 1656, was able to carry out his ideas, and the next year he presented to the govern-

ment of Holland a clock constructed after the new method. This new instrument was immediately made use of in astronomy and geodesy.

After the revival of interest in astronomy, Tycho Brahé was the first to recognize the necessity for long-continued observations upon which to base new theories. He said "Astronomy without an hypothesis was impossible," and this hypothesis must be based on the slow, long-continued labor of the careful observer. Even Copernicus, to whom astronomy owes so much, did not see the necessity for accumulating observations. He observed very little himself, but based his ideas of planetary motion on theoretical reasons. The Almagest, 1300 years old, was still the text book on astronomy. Tycho Brahé, a native of Denmark, was born about the middle of the 16th century. He began observations when he was 16 years old, and soon began to make improvements in existing instruments. His observatory, Uraniborg, was on the island of Hveen, near the coast of Norway. Here he made the largest collection of instruments known up to that time. His own private fortune and large gifts from the king of Denmark supplied the means for his work. Students came from all parts of Europe, and he soon had a large staff of observers.

I have already spoken of the quadrants used by Ptolemy. This class of instruments was still in use at the time of Tycho Brahé. He constructed a very large one and fastened it to the wall after the manner of our old mural circles. Other instruments of the ancients, while not fixed, were intended to be used in a fixed position. Tycho was the first to construct a quadrant movable in azimuth. This was the original of our present altazimuth or engineer's transit. The arc was of six feet radius, and the azimuth circle nine feet in diameter. Tycho also made great improvements in the division of circles. Before his time nearly all instruments were divided to 10′; he divided them to single minutes and by transversals to 10″. In 1542 Nunez proposed to divide the arc of a quadrant into 90 parts, then inside this arc to construct other arcs divided into 89, 88, 87, etc., parts down to 46. These divisions would enable the observer to read angles to fractions of a minute. Tycho tried this method of division, but did not meet with success on account of the difficulty of dividing an arc into 89, 87, etc., parts. Tycho also improved the sights of instruments. The former method was to observe shadows or through two holes at opposite ends of an index arm. He substituted a series of four slits and reduced the error of sighting from 2′ to ½′, or even ¼′. Tycho supposed himself to be the inventor of the sextant, and frequently

used one of $5\frac{1}{2}$ feet radius, but it is now known that the Arabs had one of 60 feet radius at Bagdad as early as 992 A. D. Tycho Brahé's work was of the utmost importance because it enabled Kepler to demonstrate his laws of planetary motion and thus to round out and complete the Copernican theory. Tycho died just before the invention of the astronomical telescope by Galileo in 1609, which completely revolutionized existing methods of observation. The engineer who has used a compass with open sights for the measurement of an angle and then measured the same angle with a good transit, has some idea of the vast improvement the telescope made in accurate measurement. But the telescope, as it came from Galileo, was not a measuring instrument. It was simply an instrument for increasing optical power. Before it could be used for measurements, means of pointing to an object must be devised. When we look through an ordinary visual telescope we see a large field of view. The telescope is not pointed to one particular object, but to the whole field. The idea of a telescopic sight first occurred to Morin, a French astronomer. In 1635 he discovered that stars could be seen in the day-time with a good telescope, and he tried to measure the distance between the moon and certain stars in the day-time, as well as at night, for the purpose of determining the longitude. But he was not able to construct an instrument to do the work. The trouble lay in the form of the telescope. As constructed by Galileo, the rays of light in the telescope were intercepted by the eye-piece before coming to a focus, and therefore there was no place where a wire could be placed. William Gascoigne, a young astronomer of England, was the first person who employed a telescope composed of two convex lenses and placed a hair at the focus. His early death, in 1644, prevented the publication of his method, but in his letters to others engaged in similar work he speaks of using a quadrant having a telescope provided with such a hair and finding the altitudes of stars with it. He also says that if the night is dark, so that the hair cannot be readily seen, he places a lantern so that sufficient light shines in through the object glass. He speaks also of fitting up his sextant with a little telescope and a thread. In another letter he says he is expecting soon to be able to read angles to seconds on account of his superior method of pointing. These letters prove that as early as 1640 telescopic sights had been used, but they do not seem to have come into general use until about 1665. The earliest published observations are those of Picard, who, in 1667, made observations in the gardens of the Royal Library at Paris with a quadrant of 9 feet 7 inches radius and a sextant of 6

feet radius, both having telescopes with threads at the focus. Picard, in his "Measure of the Earth," describes the methods of adjustment of such instruments. Among other things, he speaks of the method of reversing an instrument in order to determine its error of collimation. Several centuries before this an Arabian astronomer, Jounis, had suggested the same thing for the adjustment of the gnomon. The micrometer for measuring small distances, like the diameter of a planet, was invented at about this time. The principle of the micrometer screw was introduced by Hevelius, a native of Dantzic, who used it for division of the circle. He began his work in 1630, having instruments very similar to those of Tycho Brahé, but using the vernier which was invented by Peter Vernier in 1631. This was a great improvement on the method of transversals. Hevelius attached a fine screw to his index arm, so that after pointing to the desired object he could, by turning the screw forward or backward, bring the index to coincide with a division of the circle. Knowing the value of one division of the screw, the reading was easily determined to the fraction of a minute. This observer, however, refused to use a telescope. The combination of a telescope with threads and his tangent screw would have made his observations of incalculable value.

The desirability of some instrument for the measurement of small distances, both in astronomy and engineering, had long been apparent. By the old methods Archimedes was only able to say that the diameter of the sun was between 27′ and 32′. Tycho Brahé measured the diameters of sun and moon as accurately as possible with his instruments and found that the moon was smaller in angular magnitude than the sun, and hence a total eclipse of the sun was impossible. When the telescope revealed the discs of the planets their angular measurement became an object of great interest.

William Gascoigne, of whom mention has been made, was the first inventor of the micrometer. For reasons already given his instrument and results were not made public for many years. As early as 1638 he had constructed a micrometer which measured the forty-thousandth part of a foot, and he had applied the same instrument to his telescope. Many of his measurements of the semi-diameter of the sun are within two seconds of the true value, and his determination of the variation in the apparent diameter of the sun throughout the year is within 3″. His apparatus consisted of two strips of metal, one of which was fixed and the other movable. These were made tangent to the limbs of the body to be measured and the distance between them expressed in terms of revolutions of the screw.

We have no record of the history of his invention, but the same principle was independently discovered twenty years after on the continent. Huyghens, in 1659, pointed out the fact that an object placed at the focus of a telescope appears as distinct as the object looked at. He placed a strip of metal triangular in shape at the focus and noted where the disc of a planet was just covered by it. Then measuring the strip at that point with his dividers, he easily calculated the diameter. The Marquis of Malvasa, in 1662, gave another method of arriving at the same result. He placed a reticle of fine silver wires crossing each other at right angles at the focus of his telescope. By allowing a star near the equator to trail across them, he found their angular distance apart, and could then use the reticle to measure the diameter of any body within the field of view. If one limb of the body to be measured fell between two divisions, an estimate had to be made of that part of the diameter. This was superior to the method of Huyghens, because when the distance between the threads had once been ascertained, it could be used for any diameter or for the distance between stars. Auzout, in 1666, substituted for the reticle two silk threads, one fast and the other movable, and so reproduced the micrometer of Gascoigne, which was similar in principle to those in use to-day.

The telescope and the pendulum completely revolutionized the methods of observation. The telescope with its reticle or wires and its micrometer enabled the observer to point his instrument accurately to any part of the earth or sky and measure small distances. The pendulum, by controlling the movement of clocks, enabled the observer to definitely determine longitudes and fix the right ascension of stars. Opinion was gradually settling in favor of fixed instruments in the plane of the meridian for determining the position of heavenly bodies. Picard, of the Royal Observatory of Paris, was one of the first to advocate this, but it was not till 1683 that the observatory had such an instrument in position.

Tycho Brahé had a mural quadrant in the meridian, but it was before the time of telescopes, and hence his observations could not be compared with those made at Paris. The next step in instruments and the art of observation was taken by Römer, a Danish astronomer, who invented the transit circle and the altazimuth. His transit circle was completed in 1690, and consisted of a telescope mounted on a horizontal axis and movable only in the plane of the meridian. A vertical circle was attached to the axis and read by a microscope. A small mirror inside the tube reflected

light on the reticle. This instrument was in all essential parts except the level exactly like our modern transit circles. But the engineer was to profit by Römer's work as well as the astronomer, for he invented an altazimuth instrument which was similar to our present engineer's transit. It had a horizontal circle of 3 feet 8 inches in diameter and a vertical circle 3 feet 5 inches in diameter. Tycho Brahé had made an instrument movable in azimuth, but his, of course, had no telescope.

The Royal Observatory at Greenwich was founded in 1674 to correct the places of the heavenly bodies so that accurate determinations of longitude could be made. None of the instruments of the ancient astronomers could be used to advantage on the decks of moving vessels, and hence determinations of latitude and longitude at sea were very imperfect.

The invention of the reflecting sextant removed this difficulty. The idea of such an instrument first occurred to Hooke in England, but the idea was not given to the world. Later it was independently invented by Hadley in 1730, and by Thomas Godfrey, of Philadelphia, in the same year. From that time the sextant has been the only instrument used to determine positions at sea. Its use is too well known to need description. The repeating circle, by which an angle can be repeated an indefinite number of times, was invented by Tobias Mayer in 1756. In this instrument the errors of reading are reduced to two, one at the beginning and one at the end of the series. Maskelyne, who began work at Greenwich in 1765, was the first to observe transits of stars on five vertical wires of the telescope and to record time to tenths of a second. In 1767 he began the publication of the British Nautical Almanac, which has been published yearly ever since. Later other governments undertook similar publications. These almanacs are used by the civil engineer to determine the place of the sun in work with the solar transit and for the determination of azimuth. It has been stated that Römer constructed a transit circle for the observation of stars and that the divisions were read by means of a microscope. The idea of a micrometer microscope was first suggested in 1768, but was not applied to a transit circle till 1789, when Ramsden constructed a large instrument for Piazzi, the Italian astronomer.

The improvements in the methods of geodesy are no less interesting than those of astronomy. A few of the efforts made to determine the length of an arc of the meridian will be mentioned. The attempt of Eratosthenes has already been related. The Arabs gave some attention to this subject. The Caliph Almamoum, in

1814 A. D., sent two companies of astronomers north and south to measure distances on the surface of the earth until they found a difference of one degree of latitude, but the result was not very satisfactory. In 1500 Fernel, a Frenchman, determined a distance on the earth by counting the revolutions of his carriage wheels. He obtained his latitude by means of a triangle. In 1617 Snell measured a base line on the frozen meadows near Leyden and observed his latitudes by means of a quadrant. In 1637 Norwood, an Englishman, observed the latitudes of London and York and determined the distance between them on the public road partly by a chain and partly by pacing. Strange to say, he obtained a very fair result. It was not until 1669 that a careful determination of this important element was made by methods which have since been followed. Picard, the noted French astronomer, measured a base line with wooden rods placed end to end, and from this calculated the distance between his stations by means of a series of triangles. His angles and latitudes were measured with the best instruments of the day, provided with telescopes having cross hairs.

We have thus briefly traced the history of instruments and the art of observing from the time of the gnomon and the astrolabe to that of the transit circle and the altazimuth; from observations along the equator and the ecliptic to those along the horizon and in the meridian; from pinnules and open sights to the telescope and cross hairs; from the clepsydra to the astronomical clock. This account closes with the beginning of modern instruments.

It can best be continued by some of our own members who have brought instrumental workmanship nearly to perfection, and who will in the future, I am sure, explain to us some of the secrets of their art.

THE STATUS OF THE ENGINEER.

By George F. Swain, President of the Boston Society of Civil Engineers.

[Read before the Society, March 17, 1897.*]

I desire to call your attention, this evening, to a few general matters connected with the profession of the engineer, that have frequently occupied my thoughts.

What is the status of the engineer to-day as compared with that of members of other learned professions? What are our defects, and what can be done to remedy them? I will call your attention to but a few considerations.

And let me say here, that I do not believe there is a body of men the world over that in integrity and uprightness of character stands on a higher plane than the engineering profession—men of nerve and sinew, who grapple with the forces of nature and subdue them; men who seek only after truth, and are not concerned to make the worse appear the better reason. We should all be proud to be members of this profession; but we should the more critically survey ourselves, scrutinize our faults, and lend all our efforts to securing for ourselves the position in the world that we should justly attain.

To my mind, the principal defect among engineers to-day is a lack of breadth and culture. Engineering, in its highest sense, is no doubt a learned profession, but it is too apt to be a narrow one. In many of its branches it should, if properly practiced, require as great learning and as firm a mastery of scientific principles as any other profession. But there is, to my mind, no doubt that the engineer does not occupy as high a position in modern life as do members of the professions of law, medicine, or theology, and I believe it is mainly on account of this defect. The engineer is too often looked upon as a skilled artisan, as one who works with actual materials, but without the aid of art, and sometimes without the aid of science. There are, of course, many exceptions, but I believe that engineers to-day have, as a rule, less breadth of education and sympathy, are narrower and less cultured than members of these other professions. How many engineers are well acquainted with literature or history, art or music? I repeat, there are exceptions, but they only prove the rule. Engineers associate too exclusively with men of their own profession and not enough

*Manuscript received April 2, 1897.—Secretary Ass'n of Eng. Socs.

with leading men of other callings. This will be noticed if you examine the list of members of any important club. I have one in mind in this city, composed of scientific and literary men and artists, in which, out of a total number of 496, only 11 are engineers, while over 80 are doctors and as many are lawyers. In another prominent club in this city, which has a membership of 550, only 8 are engineers. In the Institute of Technology, with 1,196 students, 80 are college graduates, or 6.7 per cent. In the Harvard Medical School, of 454 students, 163 are college graduates, or 36 per cent. In the Harvard Law School, of 404 students, 305 are college graduates, or 75 per cent. These figures lend additional proof to the statements made above.

This condition of things is easily explainable; in fact, it could not well be otherwise. It is not that engineering is a younger profession, for it can claim an ancestry as old as almost any. Engineers had built the Pyramids long before Herodotus was born, before the laws of Moses were framed. Assyrian engineers built great bridges and reservoirs, and diverted rivers from their courses, before Hippocrates practiced the healing art, before Hipparchus observed the stars, before Euclid founded the science of geometry. The practice of engineering preceded its science. Great hydraulic works and great bridges were built before experiment had determined even the most elementary laws of hydraulics, and before the simplest principles of mechanics had been formulated.

Engineering is, therefore, as old a profession as any, unless it be that of religion, which must have had its origin when human emotions were born. This very fact, however, helps to explain its present status. Engineering was long considered as a trade, not based on science, or learning, or research. The engineer was an artisan, a builder, not a man of science. And so of old, as to-day, the builder was forgotten, while the warrior, the priest, or the legislator was remembered. We know the names of the monarchs under whom the Pyramids were built, but we do not know the names of the engineers. We know the Roman emperors under whom Rome's great bridges were built, while in many cases the builders are unknown. And so to-day, when we ask, "Who built this railroad?" are we given the name of the engineer who actually constructed it? On the contrary, the credit is too often given to some financier or promoter.

Neither is the condition of things to which I refer due to any inferiority of engineering as a learned profession. The fact is becoming recognized that engineering in its higher branches calls for a mental equipment as extensive, as elaborate, as highly specialized, and as exact as any other profession.

To what, then, is this condition of things due? As nearly as I have been able to analyze it, it seems to me to be due to three things: First, the extremely rapid strides that constructive engineering has taken within a very few years, in which the number and extent of structures built are many times as great as all that have been constructed in centuries previous; second, the fact that engineering requires the services of a large number of men, such as rodmen, chainmen, or draughtsmen, who need no learning or education whatever, or at least very little, in order to do their work satisfactorily; and, third, the fact—or what seems to me to be a fact—that, in the past, judgment and experience seem to have entered in a larger proportion into the work of the engineer than into the work of men of other professions.

Of the great development which engineering has undergone within the past fifty or one hundred years, since the childhood of the railroad and the steam engine, nothing further need be said. While I am unable to prove by figures the truth of the statement, yet I believe it to be a fact, that the value of the works constructed by engineers during this period is greater than the value of all previous works constructed by members of our profession since the beginning of the Christian era, if not since the beginning of history. Think of our present industrial development—our railways, engines, factories, steamships, bridges, water works, and engineering works of all kinds, the product of the present century. Think of the iron and steel industry of to-day, the petroleum and gas industries, the electrical industry.

This enormous development has suddenly required the services of an army of engineers, and out of this army many men with force of character, practical sense, and inventive genius, but without education, have risen from the ranks of labor to the highest positions. When this development began there were no schools of engineering. Indeed, while a scholastic education has for centuries been considered a necessary preparation for the lawyer, the physician, or the divine, engineering education is yet hardly a century old. The greatest of engineers, George Stephenson and James Watt, men to whom the world is forever indebted, had no education except what they were able to acquire themselves. Except, perhaps, on the continent, education and culture were not considered necessary for the engineer, who, as already stated, was considered an artisan. Soon, however, technical schools were established and colleges introduced technical courses, and the character of the men pouring into the ranks of the profession in this country began to change. Since that time, with occa-

sional periods of depression, engineering schools have not been able to supply a sufficient number of trained men to recruit the ranks of the industrial army, and young men with little or no education still find ample opportunity to enter the profession. Many of them go into engineering as others go into carpentry; they begin by holding a rod, and after gaining experience and some command of elementary scientific principles they may succeed in winning positions of responsibility and trust. Some of them, too, may be men of great natural ability, who are able to make up by their own efforts for lack of facilities and training which they perhaps could not afford in their youth. In England, as you all know, there was until a few years ago very little engineering education. Engineers were trained by the old apprentice system, entering the office of a practicing engineer and paying him a considerable sum yearly for the privilege of working for him and learning what they could. In the course of time they became paid assistants, or entered upon practice for themselves.

As already stated, I believe it to be a fact that, in engineering, scientific knowledge thus far has counted for relatively less in proportion to experience and judgment than in other professions. Engineering is, or at least has been, largely practical. It has depended, perhaps, more on good sense than on the calculus; more on judgment than on mechanics; more on experience than on books. This is true, I think, of all branches, though perhaps less so of electrical engineering than of others; and yet even in this branch, which is by some supposed to be extremely mathematical, and in which the science has preceded the practice, a prominent young electrical engineer, a graduate of one of our foremost colleges, being recently asked by a friend of mine how much mathematics he used in his work, said that he had no occasion to go beyond the slide rule. Scientific knowledge, however, I am glad to say, is now beginning to obtain the position which it should hold.

I must not, however, omit to call attention here to the fact that science has profited by engineering perhaps as much as engineering has profited by science. The engineer has forced a recognition of the dignity of utilitarian science. I remember even within a few years hearing an old and prominent scientist expressing deep regret that a brother scientist had condescended to devote his talents to utilitarian ends, and it seems to have been for a long time the feeling of narrow men of the former generation that a scientist should not devote himself to anything that could possibly have any practical value. What a contrast to the broader attitude

of mind which prevails at present, when the highest work of the scientist is to attack practical problems.

The reasons given above are sufficient, I think, to account for the present condition of things. The next question is, How can it be remedied? The answer is, by cultivating the humanities and the science of engineering. If the condition of things described is correct, we should first realize that it is so, and then make up our minds to improve it. No improvement is ever made by shutting our eyes to our defects. We must realize that the engineer should strive not only to make himself, first of all, a good engineer, but, secondly, a man of broad and liberal sympathies, and that in his professional work he should encourage in every possible way the science of engineering, discouraging rule-of-thumb methods, and striving to do everything in his power to make his profession rank with the other learned and scientific professions. During the last few decades our engineering schools have sprung into existence, and they have been doing a great work in improving the status of the engineering profession. But there is yet room for even greater exertion. Even the young man who graduates from one of them with a creditable record, equipped with much book knowledge, and with a command of the principles of modern science sufficient to launch him on his career, may be and generally is wofully lacking in breadth. There are many such men, and they have done and will do excellent work. But many of them somewhat resemble a Western town which has sprung up in a few years from the prairie, completely equipped with water works, electric lights, a sewerage system, street railroads, and all the appliances of modern civilization. And yet something is lacking—the mellowness which comes from association with the traditions and learning of the past. Perhaps I am wrong in the conclusions which I have reached, and yet I may truthfully say that these reflections have been forced upon me by the realization of my own deficiencies rather than by any observation of the deficiencies of others.

I have said that our engineering schools are doing a great work in improving the status of the engineer. There is a difference, however, between engineering schools, a difference between fundamental points which appears to me to have great bearing upon this question. There are two classes of such schools in this country, differing with regard to the character of the course of study. In one class this course includes not simply technical subjects, but also a fair proportion of general studies—history, literature, language, and economics. In the other class the curriculum

includes solely professional studies, without a single hour in the entire four years devoted to general subjects. It is a serious question, and a question that the engineering profession of the country must ultimately decide, which of these plans is the correct one.

Those who have charge of the schools in which no general studies are taught claim that the engineering school should be a post-graduate institution; that the young man coming there should be a college graduate, and that the engineering course should be such as to offer the fullest technical training. This, I admit, would be an ideal condition, but I believe it can never be attained in this country, where a large majority of the young men who attend engineering schools will have neither the time nor the money to take a college course first. They now come to the technical schools with essentially the same amount of preparation which students possess who enter college, and this will continue to be the case. In engineering schools, therefore, which offer only technical studies, a large majority of the graduates have been and will continue to be equipped only with the general knowledge that they have acquired in the preparatory schools. Their technical training is narrow, and tends to stifle what little interest they may originally have taken in general studies. My own feeling, therefore is decidedly against such a curriculum. I believe, however, that it is adopted largely in deference to the wishes of the students themselves and of practicing engineers.

From an experience of many years in teaching, I can testify to the difficulty of making students in engineering schools appreciate the importance of any studies not purely technical in character. Filled with enthusiasm for the profession that they are about to enter, they wish to devote themselves entirely to it, and it is only after they have neglected the opportunity to broaden themselves that they realize the loss, if, indeed, they realize it at all. And let me also express my conviction that any young man who has in him the elements of success will be a better and broader engineer, as well as a better citizen, ten or twenty years after graduating, for having devoted some considerable time during his school days to general literary or economic studies. Parents who are not engineers, generally, I think, desire to have their sons receive a broad training, and they are unable, of course, to appreciate the detail of the various courses presented in technical schools. If their son gets a course in stereotomy, they do not know or care whether it includes a very large amount of time devoted to the skew arch or not. Practicing engineers, however, and students who do not know what they ought to have, but wish

to devote themselves purely to engineering, and take no interest in anything else, are, I believe, almost always attracted by the large amount of time given in a purely technical course to the details of professional practice, and our schools are striving among themselves to see which can carry its undergraduate technical instruction to the highest point, no matter how narrow may be the graduate turned out. I am not arguing that a technical school should not endeavor to carry its instruction to the highest point, but I insist that the proper place for many advanced technical studies is not in the regular undergraduate course, but in a post-graduate course. Every student who graduates from a technical school should, in my opinion, have had a fair amount of training in general studies. Students who desire to pursue advanced technical courses, or college graduates coming to such a school, who have already completed the general studies, should find post-graduate courses ready for them.

If my view is correct, it becomes the duty of every engineer, whether he has had the advantage of a technical training or whether he has by experience, native good sense, and good judgment attained a responsible position—every engineer, I say, should lend his aid to counteract the narrowing tendencies of the profession. He should, other things being equal, in employing assistants give the preference to men who have had a technical training, and, more, he should give the preference, other things being equal, to men who have had a general training as well as a technical training. He should encourage young men to enter the engineering schools, and discourage the attempt to become engineers upon leaving the preparatory school. He should do everything in his power to broaden himself by general reading and studies, and by associating with men in other callings. Only those in a profession can raise its standard.

I do not wish to be understood as definitely advising a young man who wishes to become an engineer to take a college course before going to a technical school. I simply wish to insist that he should in some way gain a breadth of training outside of his technical studies. One way is to take a college course first; another is to go to a technical school where the course is broad, and where, if he has the time, he may spend five or more years, instead of the usual four. To discuss the relative advantages of these two plans would lead me too far, and is not necessary in the present connection.

Let us take a step further. The student graduates from the technical school and enters upon the practice of his profession.

He has been received by the profession, and its status has been altered correspondingly. According as he is good or bad, its standard has been raised or lowered. Thenceforth he must labor with the rest to improve the standard. This leads us to the proposition, which has already been stated in another way, that we should all labor to attract only the best men into the profession. One of the first questions presenting itself to the young man concerns his entrance into some engineering society, and we are thus brought to consider the relations which engineering societies should have to new members of the profession. I will consider but one question in this connection, for I have already occupied too much of your time. What should be the requirements for admission to engineering societies? Granting that the object of an engineering society is to raise the standard of the profession, and that this can be done best by encouraging the scientific element, the educational element, the broadening element, it seems to me that in the larger engineering societies there should, in the first place, be several grades of membership; in the second place, that these grades should differ very considerably in their requirements; and in the third place, that education should be considered as the equivalent of a very considerable period of experience in judging of a young man's eligibility.

No society can make its membership a criterion of ability. There always will be poor men inside and good men outside. I think the requirements for the lowest grade of membership should be very low; for the highest grade, very high. Men can but be improved by entering a professional society, and by thus improving them the standard of the profession as a whole will be raised. In the American Society of Civil Engineers a four years' technical course is considered equivalent to two years of actual practice. I believe it would be more nearly correct to reverse the figures, and consider that a technical course of two years should be equivalent to four years of actual practice. Certainly a young man who begins the practice of his profession at sixteen years of age, and by the time he is twenty has spent four years holding a rod, keeping notes, and perhaps using a transit, should not be considered the equivalent, in the influence which he is able to exert on the profession, of a young man who has spent the same four years in the college or technical school, and the difference between the two men will be brought out still more fully in the succeeding four years. To my mind, it would perhaps be nearer right to make one year of school work equivalent to one year of practice. A man of brains does not need to hold the rod for a year. If he is

equipped with the principles of his profession, and has the practical sense without which no man can succeed, a very short apprenticeship in many directions should be sufficient to qualify him for advancement. I believe, therefore, that too much weight is given to experience and too little to education, judgment, and practical good sense in the requirements of some of our engineering societies. I personally know of instances where young men have been rejected who have applied for admission whom I knew to be broader, abler, and better men in every way than many others who had for years been members.

In the case of some societies, as in our own, and local societies generally, it is impracticable to have many grades, and, in fact, there is fair ground for discussion whether it is not better to abolish grades entirely in all societies, having but one grade of membership. If this course is adopted, I am convinced that the requirements should be low, not high, as, for instance, is the case in our own society and in the American Institute of Mining Engineers, to which almost anybody is eligible. The object in this case should be to do the greatest good to the greatest number. The greatest number will always be eligible to the lower grades. If there is to be one grade, therefore, let it be a low one. Men eligible under greater restrictions will not be harmed; men eligible under low restrictions only will be benefited.

I might go further and discuss the relations of the engineering society and the technical school, but I have already occupied a longer time than I expected. I have alluded to the fact that the practicing engineer, whether he be a graduate or not, should encourage a young man to get the best education he can, and to encourage the most cordial relations between the school and the society. Members of the society should be encouraged to go to the schools for data, for experimental results, and for such other help as they can gain there, and those in charge of professional schools should realize that their success depends upon the support that they receive from the profession.

I assure you again, gentlemen, that I appreciate the honor which you conferred upon me in electing me as your president for the past year, and I am sure that the year has proved a profitable and interesting one. I predict even greater success for the year to come.

SEWER ASSESSMENTS.*

Discussion by Thomas Appleton, Member Boston Society of Civil Engineers.†

The theory of special taxes for public improvements is that the property assessed enjoys some special benefit from the construction of the improvement in question apart from the general benefit to the entire municipality. For instance, the construction of a sewer might remove ground water from a certain lot, making it possible to build a cellar which would be impracticable without such sewer. Or the construction of a sewer might make it possible to construct a building with plumbing and sanitary conveniences, which would be entirely impracticable without the sewer. Another lot in the immediate vicinity might not be able to drain into this sewer owing to the topographical features of the territory, so that an entirely different sewer would be required to afford the latter lot the same conveniences which the former ones enjoy.

It will readily be admitted that any public improvement, such as a well-planned sewerage system, which improves the healthfulness of a community, is a benefit to the entire municipality, and this benefit may extend even beyond the municipal boundaries. But this widespread general benefit cannot be as readily measured in dollars and cents and apportioned to each parcel of land as the special benefit which some particular lot enjoys, from the possibility of a direct connection with the sewer. It would also be conceded that one lot would receive a greater benefit than another from a certain public improvement, but just how much in dollars and cents the owner of a lot ought justly to pay for such a public improvement is a question requiring infinite wisdom to answer. In the nature of things, special taxes, such as sewer assessment, must be arbitrary. The power to make such assessments is usually placed in the hands of some public officer or board, and when the assessment is once made by the proper authority in accordance with the law, the courts, as a rule, sustain the assessment as made. If the question were thrown open to interested parties and their attorneys, there is ground for interminable argument on the justice of any special tax for public improvement that ever was levied.

There are many methods of levying assessments for the cost

*This discussion was received too late to appear in connection with the original paper, printed in the January, 1897, number of the Journal.

†Manuscript received March, 29, 1897.—Secretary, Ass'n of Eng. Socs.

of special improvements, all having the same end in view, but differing widely in their means of reaching that end. A good method should be a simple one which can be readily understood by the people who have the taxes to pay. Mr. Snow, in his very interesting paper on Sewer Assessments, has described various methods of making sewer assessments as followed in Massachusetts, and gives a detailed description of the rental method employed in Brockton. The writer will not attempt to criticise any of these methods, each of which has its reason for existence. He endorses Mr. Snow's statement that "every investigator can find facts to satisfy himself that, up to the present time, sewer assessments have not been made proportionate to benefits received." He will go further and say that with all the wisdom which can be brought to bear on the subject, no special assessment will ever be made that can be mathematically demonstrated to be exact justice to all concerned. Nevertheless he is confident that old methods can be improved upon, and to further this end he will roughly describe the methods which have been followed in some Western States.

In Missouri cities, sewer districts are laid out by the City Engineer and approved by the City Council. The limits of a sewer district are controlled by the topographical features. All the territory which can readily be drained by one main sewer, or, in case of large areas, by one main branch sewer, is constituted a sewer district. A system of mains and laterals is planned for this sewer district and placed on record, and thereafter the cost of any sewerage construction which is done within the limits of that district is assessed upon the entire property within the district, pro rata according to area. The area of all lots within the district, exclusive of streets and alleys, is computed, and this sum is used as the denominator in calculating any sewer assessment, the area of each lot being the numerator. While this method bears on its face the appearance of equal justice to all, it does work some hardship. In the case of combined sewers, taking the water from the streets and alleys as well as from buildings and plumbing fixtures, the improvement of the streets resulting from the sewerage may be of wide-spread general benefit, and yet the limited sewer district pays the entire cost. To partially compensate for this seeming injustice, sometimes a portion of the main trunk sewer of the district is made a "Public Sewer," and its cost is paid for out of the general fund, all extensions thereafter being paid for by special tax on the property within the district. Again, the construction of the entire district sewerage system may be a matter of years. The portions adjacent to the outlet are built first, and the lots bor-

dering on this part of the sewer are assessed just the same amount per square foot of area as the remote lots at the upper end of the district, which may not be able to connect with a sewer for years to come, even though paying repeated assessments for sewers which specially benefit other property. But in the meantime the property near the outlet, which got all the sewerage it needed when the first piece of sewer was built, has to pay its pro rata of the cost of the extensions, which benefit only the lots above it. When the extensions are built piece-meal each assessment is small and the burden of taxation is spread over several years. On the other hand, if the district is compactly built up so that sewerage is needed throughout the entire district immediately, the entire sewerage system of the district can be built at once, and one assessment pays the entire cost.

Under this plan the city disclaims all responsibility for the payment of the contractor, except in the case of a "public sewer," and on the completion of the work the contractor gets a bundle of special tax bills as full payment for his work. He then hunts up the owners of the property and collects from them as he can. As these special tax bills bear 12 per cent. interest, beginning 30 days after date of issue, they are almost as effective in collecting as the highwayman's pistol.

In a Michigan city, a sewerage system for the entire city was carefully planned and the plans placed on record. No change could be made in these recorded plans without going through a great deal of red tape. Whenever it appeared necessary to build any portion of this sewerage system an ordinance was passed by the City Council directing the work to be done, and the specified portion was built in accordance with the recorded plan. The sewers varied in size from five or six feet brick sewers down to twelve inch pipe laterals, which latter was the smallest sewer on the plan. When a sewer is built the cost of the catch basins for draining the streets is paid for out of the general fund. Then the cost of a twelve inch pipe sewer, at the same depth as the sewer actually built, is estimated, and this estimated cost is assessed upon the abutting lots pro rata according to area. The remainder of the cost is paid for out of the general fund. In this way each piece of land pays for its sewer when it is constructed, and the property adjacent to a five feet main pays only for the same size of sewer as the property adjacent to the small laterals. The assessments are divided into five parts, and one installment with interest on the remainder is paid each year, so that the burden of taxation is light. But the contractor is paid in cash, obtained by

the sale of five year bonds which are paid off as the special assessments are collected. This enables local contractors of small means to do the work and insures low prices for construction.

This method of taxation has the advantage of simplicity, and to the ordinary taxpayer seems just and reasonable. The entire municipality participates in paying for so much of the sewer as is of general benefit.

In a city in Illinois the custom was for the City Engineer to estimate the cost of a sewer ordered to be built by the City Council, and the entire estimated cost was then assessed upon the adjacent property pro rata according to area. This assessment, after confirmation by the County Judge, was placed in the tax roll and collected before the contract for building the sewer was awarded. In order to be on the safe side and avoid the annoyance and expense of a second assessment to make up any deficiency, the engineer usually made his estimate on a liberal scale, and consequently it was frequently the case that a surplus would remain after the completion of the sewer. If the contractor did not succeed in getting away with this surplus under the guise of extra bills, it would be returned pro rata to the parties who had paid the assessment, provided they were watchful enough to learn that such rebate was due them.

Under this plan the entire cost of the sewer, and perhaps more than its cost, was collected at one payment before the work was done, and the special taxes were quite burdensome. At present most of the sewer assessments are made on the five year installment plan.

In most Western cities the cost of maintenance of sewers is paid out of the general fund. Exact justice would require that those who used the sewers, or rather those whose property was so situated that they could use the sewers, should pay a portion, at least, of the cost of maintenance, and in case of a separate house drainage system, the entire cost of maintenance.

The sewerage ordinance of Brockton seems to be an attempt at equality of assessment in proportion to benefits received, but it is somewhat complicated and contains some peculiar arbitrary provisions. For instance, where one owner has property abutting on two streets, sixty feet of frontage on one street is taxed at the regular frontage rate and the balance is exempt. The equity of this provision is hard to discern. The area tax is assessed upon property within a distance of 125 feet from the street. Why this particular distance, rather than half way over to the next street, should be the limit, is not clear.

The newer Western cities, with their rectangular lots and blocks and parallel streets lead to much easier solutions of these special assessment problems than is possible with the crooked streets and irregular lots of our old Massachusetts towns.

BRADLEY & POATES, ENGR'S N.Y

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XVIII. APRIL, 1897. No. 4.

THE USE OF ELECTRIC MOTORS IN MACHINE SHOPS.

BY PROF. CHARLES H. BENJAMIN, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, February 9, 1897.*]

THIS paper will discuss the application of electricity to machine tools from the standpoint of the manufacturer and of the mechanical engineer, with a view of determining under what circumstances it is profitable to use that system of power transmission. This subject presents itself to the manufacturer purely as a business proposition free from any scientific or sentimental considerations and the question, "will it pay?" is the only one to be asked and answered.

The question of economy in manufacturing can be resolved into three principal factors which may be considered separately:

1. First cost of power and transmission plant as affecting interest and depreciation accounts.

2. Cost of motive power, including coal, water, oil, and attendance.

3. Cost of labor, to which should be added cost of interest and depreciation of machines.

1. Comparative cost of shafting and of electric plant:

One of the principal obstacles which has stood in the way of the adoption of electric transmission is its supposed great cost for installation.

An establishment which is already equipped with the necessary line shafting and countershafts might find the transition rather

*Manuscript received March 17, 1897.—Secretary, Ass'n of Eng. Socs.

expensive, but the original cost of an electric installation for a large establishment covering considerable territory is not so very much more than the cost of shafting and belts.

In one establishment in this city, employing about 300 men, the average horse-power used by machines is about fifty, and to distribute this there are 1120 feet of 3-inch shafting and 140 belts, costing, with hangers, pulleys, etc., probably about $7,500. There are about 70 machines in the shop, mostly large tools, consuming all the way from ¼ to 10 HP each, when running at full capacity.

A generator of sufficient capacity to run this establishment could probably be purchased for $1,500, while motors cost from $50 to $300 apiece in sizes varying from ½ to 10 HP. It is impossible, of course, to determine the exact number and size of motors needed in this case, without an investigation into details, but the writer is of the opinion that the cost of the shafting and belts would nearly pay for the whole electrical equipment.

In another shop in this city it takes 750 feet of shafting and over 200 belts to distribute about 20 useful horse-power to about 250 machines.

The cost of the shafting and belting in this shop is fully $3,000, a sum which would go a long way towards a complete electric plant. If a shop is lighted by electricity, the same generator may be used for power and for lighting, and thus the initial expense be reduced.

This question of first cost must be settled separately for each establishment, be it new or be it old, and, after all, it is not the most important question.

2. Comparative efficiency of shafting and of electric transmission:

In a paper presented by the writer at the December meeting of the American Society of Mechanical Engineers, it was shown that in sixteen representative manufacturing establishments of this city the loss of power by shafting transmission was very large. The average horse-power consumed by shafting and belting in six factories doing heavy work was 62 per cent. of the whole power furnished by the engine, while in six shops doing light machine work the loss was 55 per cent.

It is doubtless true that in many cases this enormous loss was partly due to complication and poor arrangement caused by rapid growth and extension of the shafting system, but this is an evil not easily avoided when shafting is used.

The amount of shafting and belting in the ordinary shop is so entirely out of proportion to the power actually used in driving

machines, as has been already shown in the examples mentioned, that one is not surprised at such a loss. As long as the engine is going, from daylight until dark, this unwieldy mass of iron and this maze of leather must be kept in motion, whether ten machines or a hundred are in operation, and this loss of power is continuous.

The average efficiency of a well-constructed generator can be safely assumed at 90 per cent., while the efficiency of small motors depends upon the kind used and the size, varying from 65 to 85 per cent. for motors of from $\frac{1}{2}$ to 10 HP. Calling the average efficiency of motors used 75 per cent. and allowing for a loss of 2 per cent. in the conductors, we have a resultant efficiency of 65 per cent.

Doubtless, by a proper selection of generator and motors a combined efficiency of from 70 to 75 per cent. can be secured in many cases, leaving a loss of only 25 or 30 per cent. for power transmission.

The transmission loss is not constant as with shafting. If a machine is stopped, the transmission loss is stopped as far as that machine is concerned. If only half the machinery is running, half of the transmission loss will be saved.

If a careful estimate could be made of the total machinery hours run for a year in almost any machine shop, it would be found that but a small percentage of the gross power is required. In fact, it has been shown in factories where electric plants have been installed that the horse-power of the generator does not need to be more than from one-third to one-half the combined horse-power of the motors.

If an electric plant is to be economical, motors smaller than one horse-power should not be used, since they are less efficient and relatively more expensive than larger ones.

The Baldwin Locomotive Works report a saving in power of from 15 to 30 per cent. where they have substituted electricity for shafting.

The Morris Safe Co., of Readville, Mass., has made a saving of from 20 to 25 per cent. in coal by using electricity.

At all times, when it is desired to use only a part of the establishment, as during times of business depression, during strikes, or when running on night work, the saving in power and time from the use of electric transmission will be very noticeable.

However, the question of saving in power like that of first cost is of relatively small importance in most establishments.

In the first case mentioned, where 300 men were employed and 70 large machines in use, the estimated cost of the shafting, belt-

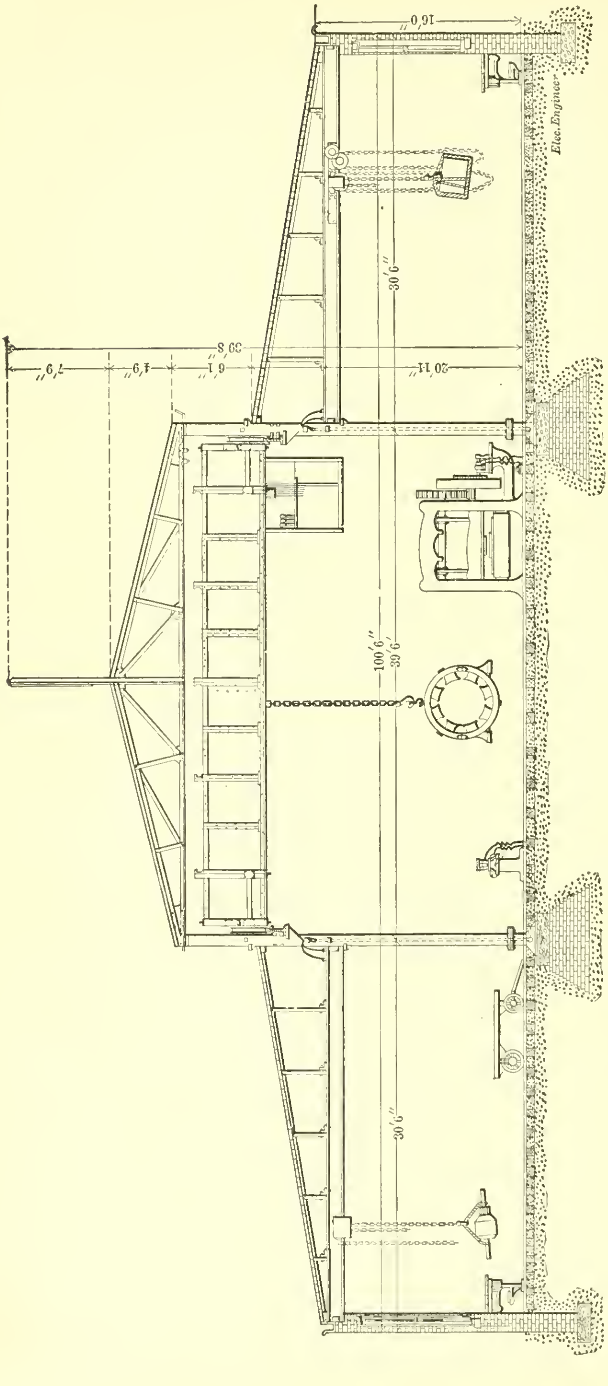


FIG. 1. MAIN FACTORY OF CROCKER-WHEELER CO., AMPERE, N. J.

ing, etc., was $7,500. Now, if we assume this to be either increased or diminished $1,000 by the introduction of electric motors, the interest and depreciation on this difference would only be $100 a year.

In this shop the gross horse-power used was 112, only 48 HP being used by the machines and 64 HP consumed by the shafting.

Assuming that only 75 HP would be needed if electric motors were used, we have a saving of 37 HP, which at $60 per HP per year would be a saving of $2,220. This factor is evidently of more importance than that of first cost, but sinks into insignificance when compared with the cost of labor. The pay-roll in this shop must be in the neighborhood of $150,000 per year when running at full capacity. A saving of 2 per cent. in the cost of labor is of more importance than any saving of power or of first cost which is likely to be effected.

3. The question of the adoption of this new form of power transmission does not hinge upon the difference in first cost or efficiency, but upon the difference in output of product per man and per machine. In other words, the main question for the advocate of electric transmission to answer is: "Will the introduction of the electric system into a factory enable the employes to do more and better work in the same time?"

Let us glance briefly at some of the advantages claimed for the system under discussion.

(*a*.) GENERAL ARRANGEMENT OF SHOPS.

In nearly all shops at the present time the general plan of the building and the arrangement of the machinery has been determined by the necessities of line shaft and belting transmission. The building must be of the right size and shape to accommodate shafting; the power plant must be located in such a way as to make connections convenient, and the machinery must be arranged in lines parallel to the shafting.

Probably most of us do not appreciate the full force of this because we have always been accustomed to it and know no other way. It goes without saying that machinery should be arranged with reference to the work, and not to the power; that it should be so located on the floor of the shop as to afford the best facilities for handling the work, for light, and for convenience in operation, and finally, that it should be possible to move the machine at any time to accommodate the work.

It is true that some of our more modern shops have achieved a moderate degree of success in arrangement in spite of the draw-

backs incidental to belt transmission. The favorite type of building for heavy machine work seems to be a one-story structure, lighted from the sides and from the roof, and arranged in aisles, one, two, or three in number, according to the size of the building.

A good example of this type of construction is seen in the works of the Walker Company, of this city, where the problem of handling and machining heavy work has been solved as well as it could be with shafting transmission.

The main factory of the Crocker-Wheeler Co., at Ampere, N. J., illustrates, perhaps, the ideal arrangement. (See Fig. 1.) The central aisle, 40 feet wide by 27 feet high, lighted from the sides and by a monitor, and accommodating an electric traveling crane, is adapted for heavy machine work and for assembling complete machines. The two side aisles, 30 feet wide by 16 feet high, are well lighted from the sides, and are intended for bench work and for lighter machines. The lower members of the roof trusses in the side aisles, 10 feet apart, each carry a hand hoist of sufficient capacity for handling all work in this department. All of the larger machine tools are equipped with independent motors attached to the frame of the machine. Some of the smaller machines are in groups, driven by short shafts located near the columns which support the main roof and not interfering with the use of the cranes and hoists. The entire arrangement is flexible and readily adapted to the work to be done unhampered by shafting and belts.

The problem of shop extension to accommodate increased business is usually a serious one where shafting is used, and is responsible for most of the waste of power in large factories. The extension of a shop in the line of the shafting is possible up to a certain limit, but when it comes to building ells and tees and wings, the choice of evils in the way of bevel gears, quarter-turn belts, and patent couplings, makes the owner shudder and the coal pile shrink.

To the man who has an electric plant it only means a few feet of wire and a few more motors, while the relative efficiency of the electric transmission as compared with shafting is in direct proportion to the acreage to be covered and the rambling character of the buildings.

(*b*.) LIGHT AND CLEANLINESS.

Probably few of us realize what a disadvantage there is in the complicated maze of belts and countershafts which is found in ordinary shops. There is no factor more conducive to increased output than plenty of light on the work.

Belts, besides obstructing the light themselves, are great dust carriers, and soon blacken the ceilings and walls near them. If an electric system is used this evil can be almost entirely done away with, and the ceilings and walls kept whitewashed or painted a light color, so as to reflect the light upon the work.

(*c.*) HANDLING OF WORK.

In all establishments except those manufacturing small machines or tools a large proportion of the time is consumed in handling the work. Time thus spent involves not only a loss of the productive power of the man, but of the machine as well. An entire absence of vertical belts permits the use of the system of cranes and hoists which shall give ready access to every tool on the floor. All wires can be carried under the floor if desired, so as to have unobstructed head room. Small machines can be grouped near walls or posts and driven by countershafts which will not interfere with the general plan.

It was for this reason that the electric system has been so largely adopted at the Baldwin Locomotive Works: It was necessary that the crane should come, therefore the belt had to go. The center aisle of the wheel shop is filled with wheel lathes instead of being used for a setting-up room, as in so many shops; consequently it was impossible to introduce cranes without at the same time introducing electric power. The force of thirty or forty laborers formerly employed to handle work has been reduced to eight or ten; the time lost in handling, formerly from 8 to 10 per cent. of the entire time, is now less than 2 per cent. Incidentally, the saving in power has been from 15 to 30 per cent., as before noted.

That the new system has been a success in this case is shown by the fact that it is being gradually extended to cover the entire works.

The traveling crane can also be utilized to bring the tool to the work when the latter consists of an unwieldy casting like an engine bed. Drills, shapers, and slotting machines having independent motors, can be transported to any part of the shop in a few minutes, and three or four can sometimes work on one frame at the same time. The Crocker-Wheeler Co. even goes so far as to show a lathe traveling through the air in the clutches of an electric crane, and all the while contentedly chewing away on its work.

The development of small, quick-acting electric cranes is sure to follow this opportunity for their use, until we shall see them take the place of hand-hoists over the smaller tools in the shop.

(*d*.) CONTROL OF SPEED.

Whenever an independent motor is used on a machine, if the motor is properly designed the speed can be changed instantly by the controller without any change of belt. In facing up work on a lathe or boring mill this is an important consideration, since the speed can be gradually increased as the tool nears the center, and the output of the machine will be so much the greater.

In experiments made on a 42-inch engine lathe equipped with a motor headstock, 27 different speeds were obtained by the mere moving of a handle, the change from greatest to least speed being effected instantly if desired.*

In addition to this it was found possible to develop 25 per cent. more power from the lathe than from a similar one driven by a belt in the ordinary manner. If it is possible to do this on all large machines the superiority of the electric drive on the all-important question of production is manifest.

Another possible advantage which should be noted is the practicability of using the same electric current for lighting the shops both by incandescent and arc lamps, and also use it for annealing, case-hardening, brazing, soldering, and welding, which latter operations might be effected locally, in the case of large machines, after they are assembled. Electricity is a very useful servant to have always at hand in any part of a large shop and is just beginning to be appreciated.

To sum up briefly the advantages claimed for electric transmission, they may be thus stated:

The possibility of arranging the shops to suit the nature of the work and the convenience of the workmen.

The capacity of indefinite extension.

A clear and open space above the machines, insuring better light and quicker handling of work.

Immediate adaptation of speed to the work being done with resulting economy of the time of man and machine.

It has been urged that the care of so many motors and generators would involve a greater expense for attendance, and that the repair bill is likely to be a large one.

It may be admitted that if the same care which the motors require were expended on the shafting the latter might make a better showing as to efficiency than it does at present.

The writer has had under his observation two Sprague motors, each rated at 3 HP and belted to line shafts about 80 feet in

*See Cassier's Magazine, February, 1895.

length. These are used intermittently when the engine is not running, and often develop considerably more than the rated horsepower. They have been in use now for about five years and require no more attention than any ordinary counter shaft; they run at a constant speed irrespective of load and cause no trouble from sparking. The repair bill for brushes, dressing commutator, etc., will compare favorably with those for belting and lacings, while breakages of machinery due to any sudden overload are almost impossible, the only damage being the blowing of a fuse.

EXAMPLES OF ELECTRIC TRANSMISSION.

It would not be practicable in a paper of this kind to enumerate the various establishments which have wholly or in part adopted this form of transmission, and only a few of the more notable examples will be given.

It is worth noticing that the manufacturers of electrical machinery have usually the courage of their convictions and swallow their own medicine manfully. The Crocker-Wheeler Co., the General Electric Co., and the Westinghouse Electric Co. are of this number.

The shops of the Crocker-Wheeler Co., at Ampere, N. J., are probably the best examples of electric transmission in this country, if not in the world. In these shops there is an entire absence of overhead shafting and belts, as all the large tools are driven by direct connected motors, while the groups of smaller tools are driven by short shafts in such a way as not to interfere with head room. The wires are carried along the roof trusses, down inside the columns, and then under the floor to each machine or motor. The delightfully clear and light appearance of the interior is in marked contrast to the gloom and dirt of the ordinary shop.

The General Electric Co. has shops driven entirely by electricity furnished from a central steam plant. A great number of direct connected motors are used on the larger machines, while some smaller machines are bunched in groups of two or three, each group having its separate motor.

For ordinary shop work the usual long shaft is cut into two or three parts, each part being driven by a motor on a bracket at the side of the building. Many of the larger slotting and shaping tools are capable of being carried to the work by a crane.

The shops of the Westinghouse Electric and Manufacturing Co. are equipped throughout with two-phase Tesla motors, the power being furnished by a central steam plant aggregating 2,500 HP. These shops, like those of the Crocker-Wheeler Co. illus-

trate the modern form of construction as adapted specially to this form of transmission. The main building, the machine shop, consists of a structure 754 feet long by 231 feet wide, covering four acres of ground and divided lengthwise into three aisles. The central aisle of this building, lighted by monitors and skylights, is entirely clear of overhead belts, and shows the same clear and bright appearance as those before noted. Most of the machinery in this aisle is belted to short side lines of shafting, driven by independent motors of from 10 to 50 HP, and not interfering at all with the two 30-ton electric cranes which traverse the building from end to end.

Some of the larger tools are driven by independent motors. The other shops of the company, extending over a tract of some forty acres, are all driven from the same power plant. The two-phase motors employed require less attention than the ordinary motor, on account of the absence of a commutator.

Several large establishments devoted to manufacturing other than electrical have become converts to this new gospel, notably the Baldwin Locomotive Works, before mentioned, and the works of the Carnegie Steel Co., at Homestead and at Cochran.

At the Baldwin Works Westinghouse motors are used, and in most cases are belted to the machines to be driven. It is remarked as a strong argument in favor of the electric drive that the men in these shops, who work mostly for piece prices, prefer the electrically-driven machines.

The Homestead works of the Carnegie Steel Co. have over 400 motors in use. All of their new heavy machine tools and many of the old ones being thus driven.

Many of the new tools are specially designed for electric driving, and have direct connected motors on the frame of the machine. The motors used here are direct current, compound-wound machines.

The Westinghouse Co. has recently furnished to the Carnegie works at Cochrane two 500 HP direct current generators and a number of motors, to be used throughout the plant.

A reference to the leading electrical journals will give the inquirer descriptions of these and of numerous other recent installations in much more detail than is possible here.

REQUIREMENTS.

It is not the purpose of this paper to go into a discussion of the different types of motor in use or to try to decide on the best for this kind of work. Perhaps it will not be out of place, how-

ever, to mention the requirements which should be met if the experiment is to be a success.

In general motors of less than one HP should be avoided, as they are expensive relatively, frail and inefficient.

For use on line shafting or counters the motors should be simple in construction, have the very best of oiling devices, and should be iron-clad or protected from dust to the greatest extent consistent with good ventilation and cool running. They also should be capable of controlling the speed under sudden variations of load.

The requirements for a direct connected motor are even more severe. The motor which is connected directly to a machine tool must be under perfect control, so that the operator may stop or start it instantly and may, within certain limits, obtain any variation of speed without sparking at the commutator and without seriously impairing the efficiency.

It must also be so made as not to induce magnetism in the iron work of the machine itself to such an extent as to cause any inconvenience in operation.

Finally, the motor must not cost too much. The construction of electric motors and generators is even now in the experimental stage, and has not been reduced to a system, as in the case of steam engines or sewing machines, and the cost of the labor is out of all proportion to the cost of the material. With increased demand and production on a larger scale, this fault will mend itself.

If you ask what motor will satisfy all these conditions, that is the question for the electrical man to answer.

GENERAL CONCLUSIONS.

The question which most interests the manufacturer is: "Will it pay me in dollars and cents to put in an electric plant?"

The answer to this question would depend entirely upon circumstances. Generally speaking, if it is proposed to introduce motors into a shop already fully equipped with shafting, the chances are much more unfavorable to electricity than in a prospective shop.

Simply substituting motors for main belt drivers and leaving the line shafts and counters in place would be a doubtful experiment, since it would deprive the new system of its principal advantages, light and clear head room, and would saddle upon it all the disadvantages of the old system.

Even if it is decided to throw out the old shafting entirely, the building as designed may be ill adapted to secure the advantages sought.

It is to those who are to build that this new plan will appeal most strongly. Such will be able from the outset to so plan their buildings and arrange their machinery as to secure all the advantages of the electric system.

Some of the shops already mentioned show what can be done in this way.

Small, compact shops having a large number of small machines of a similar character and having comparatively short lengths of shafting, would show little saving from the introduction of motors, especially if the work be of such a character as to be most readily moved or lifted by hand.

On the other hand, in all shops which cover a large extent of territory, with machines widely scattered and more or less intermittent in their action, the introduction of electricity would be a paying investment, even if it had to displace a pre-arranged equipment of shafting, as in the Baldwin works.

The relative economy of electricity as a means of transmitting power increases with the distance, and each man must decide for himself on which side of the line he may be.

THE 100-FOOT STANDARD OF LENGTH OF THE BOSTON WATER WORKS AT CHESTNUT HILL RESERVOIR.

By Charles W. Sherman, Member of the Boston Society of Civil Engineers.

[Read before the Society February 17, 1897.*]

Within the past year it has been my privilege to set up, under the direction of Mr. Desmond FitzGerald, Past President of this Society, a 100-foot standard of length for the Boston Water Works, and I propose to give a brief description of it, and of some of the problems which came up in graduating and testing it.

The Boston Water Works standard is patterned in many respects after the so-called Bench Standard of the United States Coast and Geodetic Survey. The latter consists of an iron bar 2 inches wide and $\frac{7}{16}$-inch thick, resting on brass rolls which in turn rest on the bench. It is a little more than 100 feet long, and is graduated from zero every 3 feet to 99 feet and every 10 feet to 100 feet, the graduation marks being on german silver plugs which are set into the iron. There is also a division into meters on another set of plugs. The English measures are standard at 62° F., and the metric at 0° C. (See Fig. 1.) In making a comparison, the tape is laid out upon the bar, its zero fastened opposite that of the standard and the required tension applied by a spring balance at the other end. The correction for the tape is then obtained by a direct comparison, using a small scale, or in some cases micrometer microscopes.

The great advantage in having an iron or steel bar for a standard is, of course, that its coefficient of expansion by heat and that of the tape are very nearly the same. The officers of the Coast Survey are accustomed to assume that the coefficient of a steel tape is the same as that of their bar, and the error thus introduced is generally inappreciable. If then the tape and the bar are at the same temperature during comparison, the observations give the errors of the tape without any correction for temperature. It is therefore not important to know the absolute temperature of comparison with a great degree of accuracy.

The construction of a standard for the Boston Water Works was decided upon in 1894, and a bar of steel 1 inch × $\frac{1}{4}$-inch in

*Manuscript received March 18, 1897.—Secretary, Ass'n of Eng. Socs.

cross-section, rolled in one piece 105 feet long, was obtained from the Crescent Steel Company, of Pittsburg, Pa. It was bent into a coil about 5 feet in diameter for transportation. Nothing further was done toward the construction of the standard until the spring of 1896.

The only place on the Chestnut Hill Reservoir grounds in which the standard could be located without setting it on posts in an open field is on the north side of an open shed 100 feet long,

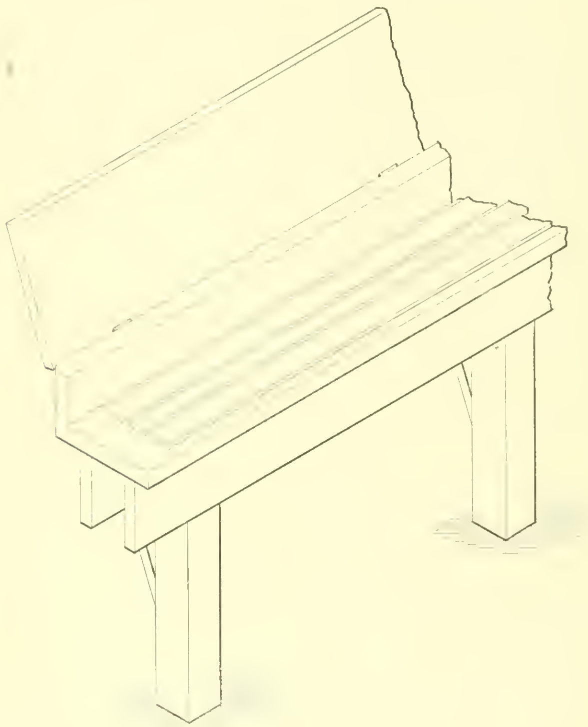


FIG. 1. U. S. C. AND G. S. "BENCH STANDARD."

where it could be bracketed off from the building. The shed serves pretty well as a protection from the sun, and the shrubbery acts to some extent as a wind-break. (See Fig. 2.)

The bench (see cross-section, Fig. 3) is built of 2-inch white pine plank, and is supported by brackets from the posts of the shed. These posts are 8 × 8-inch timber, and about 12 feet apart, and there is a bracket spiked to each side of each post. The construction of the bench is clearly shown by the cross-section. The planks

Fig. 2. General View.

on edge are about 10 inches deep, and the width of the bench is 8 inches. Since the bar is more than 100 feet long, there is an overhang of about $3\frac{1}{2}$ feet at each end of the shed. The brackets are made of spruce, the remainder of the bench of selected white pine. The cover, for protection from the weather, is in thirteen sections, with battens over the joints.

The bar rests on composition rolls $\frac{9}{16}$ inch in diameter and spaced one foot apart, which turn in bearings screwed to the bench. At the center the bar is held by a clamp or vise, to prevent the whole bar from moving on the rolls. At each side of the bar is a

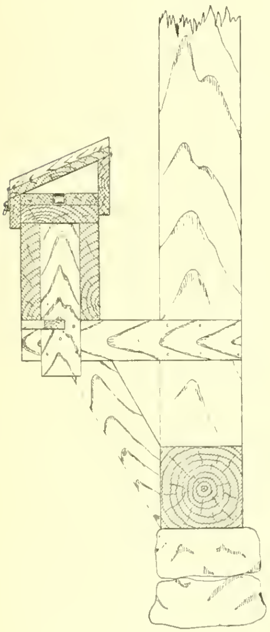


Fig. 3.

Cross Section of Bench.

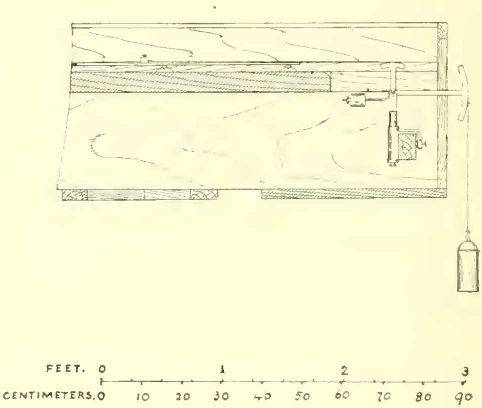


Fig. 4.

Longitudinal Section of Bench, with Apparatus for Stretching Tape.

$\frac{7}{8}$-inch board, bringing the surface of the bench even with that of the bar, but leaving a space of about $\frac{1}{16}$ inch on each side.

The bench was built and the rolls put in position before the bar was straightened. When the bar was uncoiled it was found to be in very bad condition, due partly to rough handling in transportation and partly to its never having been properly straightened. A blacksmith and helper worked on it for two days and then did not get it perfectly straight. If I were to build another standard, I should specify that the bar should be put through

straightening rolls at the mill, and then carefully coiled on a wooden reel made for it, with edges nailed on to hold the coil in a plane.

After the bar had been straightened, the approximate positions for the graduations, which are ten feet apart, were marked, and a $\frac{3}{4}$-inch hole drilled about $\frac{3}{32}$ inch into the steel at each of these points, and a disc of silver hammered into the hole. The mistake was made of having the surface of the silver brought flush with that of the bar; it would better have been left very slightly projecting, as the surface of the silver could have been more easily finished.

The manner of applying the required tension to the tape is clearly shown in the longitudinal section (Fig. 4). The apparatus consists essentially of two lever arms at right angles, each carrying an arc whose center is at the knife-edge on which the apparatus turns. Cords pass over each of these arcs, one of which is connected to the tape, while the other supports a weight. Since the lever arms remain constant as long as the cords are tangent to the arcs, the adjustment of the tape in the required position is very much simplified. This apparatus is practically the same as that designed by Mr. H. C. Bradley and used by Professor Burton in his base-line measurements.

The graduations of this standard were obtained from the United States bench standard by comparison with two steel tapes which had been carefully tested by the Coast Survey and their corrections determined.

In making the graduations, a transit was first set up at the end of the bar so that its line of sight passed as nearly as possible through the centers of all the silver discs, and this line was marked on each disc with the point of a knife. The end graduations were then transferred approximately from one of the tapes and marked by light scratches at right angles to the first. A series of comparisons between the bar and the tapes was then made, from which the probable length of the bar was computed. With the aid of a small scale, the correction to make the length of the bar 100 feet was laid off, and a point for the final graduation marked.

The positions for the ten-foot subdivisions were found by dividing the whole length of the bar into ten equal parts with the aid of a kind of beam compass. This consisted of a wooden straight-edge about $10\frac{1}{2}$ feet long, to which were fastened two steel points ten feet apart, as nearly as we could set them. By spacing back and forth along the bar the positions for the subdivisions were found with a good degree of accuracy.

The graduations are marked by a point instead of a cut. The point was sunk into the silver with a very fine center punch, after which the surface of the silver was finished off, leaving an excellent graduation.

The view, Fig. 2, shows the standard with the tape laid out for comparison. The stretching apparatus is shown quite clearly. The pull on the tape is twelve pounds, and the weight is five pounds.

The method of making the comparison is this: The observer at the zero end sets the zero of the tape with that of the bar, using an ordinary reading glass. This is accomplished by means of a screw, by which the tape can be drawn up or let out, and this can be done without paying any attention to the balance and weight further than to see that the cords always remain tangent to the arcs. The graduation mark on the tape is of considerable width, usually about .02 inch, and it is the object of the observer to set the center of this broad mark opposite the graduation of the bar. When he has set the tape in the proper position, he calls to the observer at the other end, who immediately reads the comparison, with the aid of a small scale.

The method of reading this comparison I want to describe in some detail. It seems a rather rough method, and was first used as a makeshift, but I soon found that it gave very good results. The scale used is a three-inch triangular drafting scale, divided to fiftieths of an inch. One of the graduations of the scale is set by hand in coincidence with the graduation of the standard, and then, when the observer at the zero calls "All right," the position of each edge of the broad graduation mark of the tape is read on the scale, estimating to tenths of one division of the scale, or .002 inch. A careful observer can do this with a very good degree of precision. The mean of the two readings then taken is the difference in length between the tape and the bar.

To finally determine as closely as possible the true length of the bar, a long series of comparisons was made with the two tapes which had been standardized by the Coast Survey. The results of these comparisons I want to discuss in a moment, but first I will mention some of the precautions taken to eliminate errors of observation. The settings of the zero of the tape with that of the bar and of the small scale were made afresh for each reading of the comparison. To eliminate personal error, the observers changed ends after each five observations. To determine whether the friction between the tape and the bar was an appreciable quan-

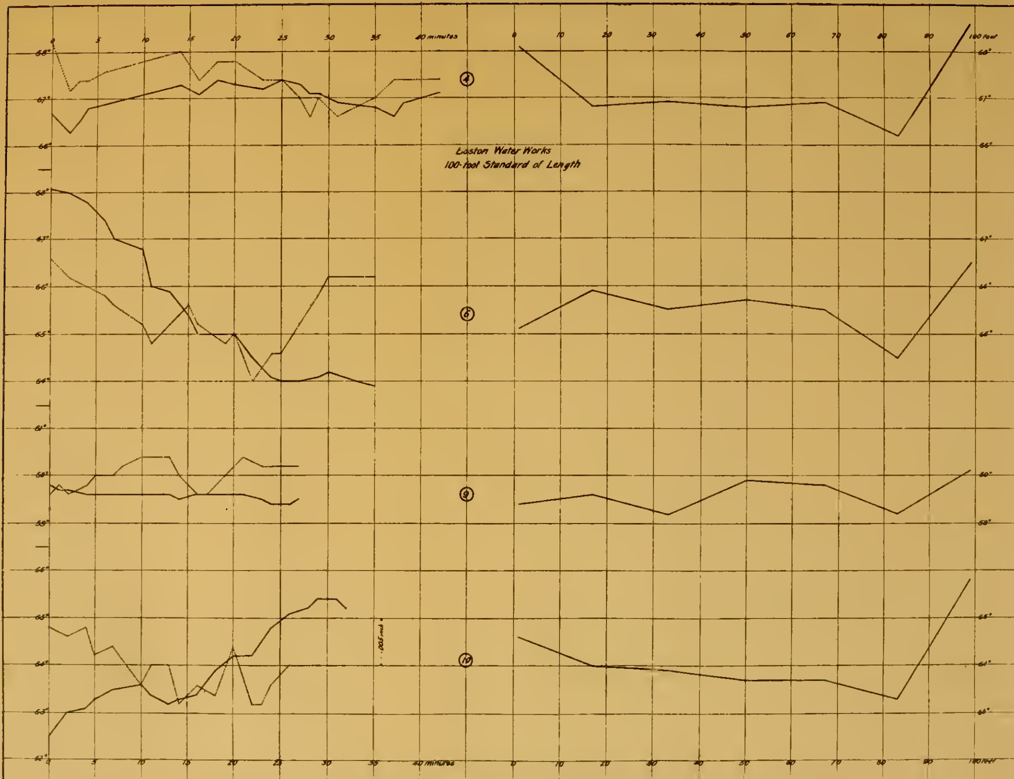


FIG. 5. DIAGRAM SHOWING VARIATIONS OF TEMPERATURE AND OF COMPARISONS.

tity, the zeros were set together both by drawing up and by letting out the tape, but no difference could be detected in the readings.

Thermometers were placed with their bulbs in contact with the bar at 1, 17, 33, 50, 67, 83, and 99 feet from the zero, and were read immediately after each comparison. Of course, their readings do not truly represent the temperature of the bar, for a very small part of the bulb is exposed to the bar as compared to that exposed to the air; but the mean of the readings of the seven thermometers gives at least an approximation to the mean temperature of the bar. The temperatures are not needed for reduction, since the assumption is made that the coefficients of expansion of the tape and bar are identical. They are, however, used in the discussion of the results.

The comparisons for determining the length of the bar consist of sixteen series, usually of twenty observations each. The mean length of the bar was first found for each series, and these results adjusted by the method of least squares to give the most probable length of the bar. Nine series of comparisons were made with tape No. 148, and seven series with No. 76. Each series is given a weight, in the adjustment, which depends on the number of observations and also on the rapidity with which the temperature was changing. For each series a temperature curve has been plotted, in which ordinates represent the mean temperatures of the bar and abscissas represent times. (Diagram, Fig. 5). The temperature factor in weighting the series is the cosine of the mean inclination of this temperature curve. The cosine has been used because it is unity for a horizontal line, or no change of temperature, and zero for a vertical line, or an infinitely rapid change of temperature. This cosine has been taken by scale from the diagrams, and is, of course, an arbitrary quantity, depending on the relative scales to which time and temperature are plotted. I have used a scale of one inch to one degree, and one inch to five minutes. It is obvious that a thin piece of metal like a tape would respond to a change in the temperature of the air much more rapidly than would the bar, and consequently the more rapid the change of temperature the less closely would the temperature of the bar and tape agree, and the less accurate would be the results. The above assumption of weights is therefore believed to be logical.

The diagram (Fig. 5) shows the variation in mean temperature of the bar during four of the comparisons or series of twenty observations each. It also shows on the right the variation of the mean temperature from point to point along the bar. It will be nóted that there is a low point at the 83-foot mark. This

was observed in all but one or two of the comparisons, and is probably due to a gap in the shrubbery. The dotted lines on the left show the variations in the reading of the comparison between tape and bar, plotted to a very large scale. These lines were drawn to see whether or not the variation in comparison followed closely the change in temperature. As you see, in some cases it did, while in others it seemed to go directly opposite.

A series usually consisted of twenty observations, as I have already stated. When less than twenty observations were taken, the weight of the series was reduced in direct proportion to the number of observations.

The mean values found for the length of the bar are, from tape No. 148,

$$100 \text{ ft.} - .0046 \text{ inch} \pm .0009 \text{ inch};$$

and from tape No. 76,

$$100 \text{ ft.} - .0154 \text{ inch} \pm .0022 \text{ inch}.$$

The difference in the absolute value of the standard as determined from the two tapes is not surprising, for the lengths of the tapes were determined at Washington by only two observations for each tape, and then at temperatures considerably above 62°. But the probable errors of two determinations ought to have been very nearly alike. Although the comparisons were all made with the same care, the comparisons with the tape No. 76 differed quite widely among themselves. No reason for this variation has been discovered. The results obtained with tape No. 148 were consistent, and thus we have a small probable error.

Combining these two values for the length of the bar according to the principle that their weights are inversely proportional to the squares of their probable errors, the most probable value for the standard is found to be

$$100 \text{ ft.} - .0061 \text{ inch} \pm .0019 \text{ inch at } 62° \text{ Fahrenheit}.$$

In order to determine the values of the ten-foot subdivisions of the bar, each ten-foot space on each of the standard tapes has been compared with each of the subdivisions of the bar. Taking the means of these comparisons, and applying the condition that the total length of the bar is 100 ft.—.0061 inch, as found above, the resulting values for the subdivisions are found to be:—

Space.	Value.
0— 10	10 ft.—.0001 inch.
10— 20	10 " —.0027 "
20— 30	10 " +.0025 "

30— 40	10 "	—.0005 inch.
40— 50	10 "	—.0014 "
50— 60	10 "	—.0006 "
60— 70	10 "	—.0046 "
70— 80	10 "	+.0032 "
80— 90	10 "	—.0027 "
90—100	10 "	+.0008 "

To determine the coefficient of expansion of the bar, I have set in the ground under each end of the standard a post, with a zinc plate nailed to the top. The positions of the ends of the standard are transferred to the zinc plates by means of an engineer's transit set with its line of sight at right angles with the bar. The temperatures are taken with the thermometers, as in a comparison, but in this case, immediately after the temperature observations a thermometer is inserted at the center of the bar in such a position that its bulb is in contact with the under side of the bar. One-half the difference in temperature between the upper and lower sides of the bar at the center is added to or subtracted from the mean temperature previously found, and the result assumed as the correct mean temperature of the bar.

Thus far I have been able to observe a change of temperature of only 23.6° Fahrenheit. The resulting coefficient of expansion is found to be .00,000,639,7 per degree Fahrenheit. That of the United States bench standard is .00,000,63.

An error of 1° Fahrenheit in determining the difference in the mean temperature of the bar would have caused an error of .00,000,026 in this coefficient. I have no reason to think there is an error of even .25 degree, but other observations will be taken when the warm weather comes, and the coefficient determined with a much greater certainty.

Since completing the standard I have made a short investigation of the errors of graduation of various makes of tapes. The results are too few in number to permit us to draw any general conclusions, but are here given for what they are worth.

The tapes tested were all new. Eight of them—two each of four different makers—were kindly loaned me for the investigation by Messrs. Buff & Berger, and were taken at random from their stock. The tabulated figures give the true lengths of the tapes. Nos. 76 and 148 were tested by the Coast Survey, and are the standard tapes from which this standard was laid out. All the tapes were tested under a tension of twelve pounds.

Number.	Maker.	Length.
10	Chesterman	100.0153 feet.
11	"	100.0176 "
12	"	100.0170 "
13	Lufkin	100.0023 "
14	"	100.0023 "
15	K. & E. "Excelsior"	100.0098 "
16	" "	100.0087 "
17	Eddy	100.0001 "
18	"	100.0068 "
76	"	100.0018 "
148	"	100.0003 "

With regard to the Chesterman tapes, it seems probable that they are intended to be correct when laid out flat, but subjected to no tension. A rough test with an old Chesterman tape, the only one available at the time, showed an elongation in 100 feet of .021 foot under a twelve-pound pull, or a little more than the error found for the new Chesterman tapes when subjected to a tension of twelve pounds.

In closing this paper, I desire to express my obligations to many friends, and particularly to Mr. C. L. Berger, for hints and suggestions which have proved of great value to me.

DISCUSSION.

Mr. Frank O. Whitney.—The first standard for measuring by the City of Boston, of which we have any knowledge, was laid down upon the floor of the office of the City Engineer, at what was formerly known as No. 119½ Washington street, and was marked by tacks driven in the floor. This standard was fifty feet long, and was in use from 1851 to 1860.

It is not known that it was established by any specially scientific method, but was understood to be carefully laid off with sufficient accuracy to serve the purposes of the time. After the removal of the City Engineer's office in 1860 to the building recently vacated by the Suffolk Registry of Deeds, a standard was established on the westerly curbstone of Pemberton Square.

This standard was laid off by means of a ten-foot mahogany pole, which was carefully prepared by Mr. Temple, the well-known instrument manufacturer, and was tested by the City Engineer, who compared it with the United States brass standard, deposited with the Secretary of State, at the State House.

This standard was marked by copper nails in three lead plugs driven into drilled holes in the curbstone fifty feet apart.

This standard was tested March 5, 1864, by means of the ten-foot pole and found to be .014 of a foot too long.

Comparison was made with a standard established by Mr. Henry W. Wilson, at South Boston, and found to be .01 of a foot shorter than Mr. Wilson's.

Messrs. Shedd and Edson had, in the passageway near Pemberton Square, a hundred-foot standard, which agreed exactly with the city standard.

After the erection of the present City Hall in 1865 the standard was transferred to the granite walk in the rear of the City Hall on Court Square.

This new standard was marked by cross lines upon three brass bolts driven into the granite fifty feet apart, thus making a standard one hundred feet long.

Very early in its existence it was carefully tested with the Coast Survey base.

June 23, 1867, Mr. C. F. Baxter compared the standard in Court Square with the old one in Pemberton Square and found the new standard to be .015 of a foot shorter than the old one.

For many years this standard stood undisputed, and was generally used by the surveyors of Boston.

In 1878 at a meeting of this society a member made a statement which tended to throw discredit upon the standard and it was claimed that either the standard was never correct or that it must have undergone a change.

A very thorough testing of the standard under the direction of the City Surveyor was then undertaken.

This test was very carefully made by Mr. S. C. Ellis, assisted by the writer.

A comparison was made with the State standard furnished by the Government, by means of a steel bar three feet long, made by Darling and Sharpe, and tested by Professor Wm. A. Rogers, of the Cambridge Observatory, who was an acknowledged expert in very fine measurements.

It was found that this bar agreed with the State standard at a temperature of 79° Fah.

Professor Rogers compared this steel bar with two end measure bars made by the United States Coast Survey for the Stevens Institute, of Hoboken, New Jersey. These bars were marked Bar B and Bar E. Two series of tests were made at a temperature of 59.1° Fah. with the following result:

FIRST SERIES.

Darling and Sharpe bar longer than Bar B at top .00512 inch.

Darling and Sharpe bar longer than Bar B at bottom .00461 inch.

Darling and Sharpe bar longer than Bar E at top .00490 inch.

Darling and Sharpe bar longer than Bar E at bottom .00423 inch.

SECOND SERIES.

Darling and Sharpe bar longer than Bar B at top .00512 inch.

Darling and Sharpe bar longer than Bar B at bottom .00460 inch.

Darling and Sharpe bar longer than Bar E at top .00478 inch.

Darling and Sharpe bar longer than Bar E at bottom .00429 inch.

Comparing these results with that obtained from the State bar test, and allowing for the contraction of brass, we find that if the Stevens Institute bars were right at 60° Fah. the State bar would be right at 50° Fah.

Professor Rogers made a test of the State brass standard and stated that he found it to be correct at 50° Fah.

As the temperature at which the State standard was supposed to be right was unknown, Mr. Davis wrote to Professor Hilgard asking for information.

Professor Hilgard replied that the temperature of comparison should have been certified on a card accompanying the bar, but in its absence it would be difficult to ascertain, as the bar was delivered previous to 1842, and the records prior to that time have been destroyed by fire.

He stated that he considered the Troughton scale which represents the standard to be right at nearly 60° Fah., although it was originally intended to be at 62°.

It would seem that the comparison with the Stevens Institute bars would more nearly represent the true standard.

The Boston standard which was found to agree with the Rogers interpretation of the Coast Survey standard has been carefully compared from time to time with a tape used solely for that purpose, and there is every reason to believe that it stands to-day as nearly correct as it is possible to maintain a standard hundred feet.

It has been impossible to discover any change between the highest and lowest temperatures.

The most extensive work requiring a high degree of accuracy in long measurements ever undertaken in this vicinity is the coordinate survey of Boston, commenced in 1891, and now in progress.

In this work it has been difficult to connect lines measured on

the Boston standard with the Coast Survey without a reduction of about .003 of a foot from said standard.

While this may not be discovered in the methods employed in former tests of the standard, it does become apparent when that standard is multiplied a hundred times.

This difference may, however, be largely accounted for by the limit of error allowed by the Coast Survey in determining secondary and tertiary positions, as there is only one primary position accessible.

Mr. Charles W. Sherman.—The standard in the sidewalk behind the City Hall was tested by me on December 22, 1896, by comparing it with our two standard steel tapes. The method of comparison was similar to that already described, but in this case it was necessary to apply the pull by hand at each end, and the tension was measured by a spring balance. Then, too, the marks on the brass bolts are not fine enough to permit so close a comparison as with the Chestnut Hill standard. The temperatures were taken by two thermometers placed approximately opposite the 25-foot and 75-foot points. It was not possible to put the thermometers in contact with the tape, because of the large number of passers-by, and the lack of sufficient assistance to guard the thermometers. They were accordingly placed against the building, about two feet from the tape, and in contact with the sidewalk.

It should be noted that the flags of the sidewalk cover a vault, in which part of the heating apparatus of the City Hall is located. The sidewalk is therefore always warmer than the air in winter, and as it is on the north side of the building, it is usually cooler than the air in summer. During this comparison it was noticed that if the thermometers were lifted from the sidewalk the column immediately went down.

The results of the comparison are as follows:

	Tape No. 76.		Tape No. 148.	
Mean Tempr. (Fahr.)	30°.0	30°.1	29°.9	30°.1
Length of Tape at this Temp.	100 ft.—.22 inch.	50 ft.—.10 inch.	100 ft.—.24 inch.	50 ft.—.13 inch.
Comparison	+.26 inch.	+.15 inch.	+.25 inch.	+.12 inch.
Length of Standard	100 ft.+.04 inch.	50 ft.+.05 inch.	100 ft.+.01 inch.	50 ft.—.01 inch.

The means of these values for the standard are

100 ft.+.025 inch.
50 ft.+.020 inch.

If the temperatures of the tapes differed from those given by the thermometers, which is possible, they should doubtless be lower than the figures given above. This would show the standard to be more nearly correct than the above figures would indicate.

From this test I should say that the sidewalk standard was correct within .002 foot, and that the error is in the first or left-hand 50 feet of its length.

EUROPEAN BOILER PRACTICE.

R. S. HALE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, February 17, 1897.*]

In the spring of 1896 the Steam Users' Association, organized by Mr. Edward Atkinson, did me the honor of selecting me to visit Europe and to make them a report on European boiler practice. The present paper is largely taken from that report with the kind permission of the Association.

TYPES OF BOILERS.

The standard type of boiler, with the exception of France and the Province of Elsass (Alsace), in Germany, was decidedly the internally fired flue boiler known as the Lancashire when it has two flues, and the Cornish when it has one.

Table I., prepared by Mr. Hiller, of the National Boiler Insurance Co., Manchester, shows the distribution of the various types of boilers in Europe.

TABLE I.

PER CENT. OF BOILERS OF VARIOUS TYPES.

Country	United Kingdom.	France.	Germany.	Switzerland.	Austria.
Year	1895.	1893-4.	1893-4.	1893-4.	1893-4.
Lancashire and similar Types	38	4.7	35.7	19.6	29.7
Cornish and similar Types	23.7	8.2	15.3	40.8	
Externally Fixed Cylindrical, including Elephant	6.8	57.3	14.8	15.5	41.0
Externally Fired Multitubular		13.4	5.2	3.5	7.5
Locomotive	11.0	5.1	17.3	5.7	10.5
Small Verticals	16.6	3.6	5.0	13.5	6.1
Water Tubes	1.8	5.7	4.6	1.4	3.8
Other Types	2.1	2.0	2.1		1.4
	100	100	100	100	100

*Copy received March 18, 1897.—Secretary, Ass'n of Eng. Socs.

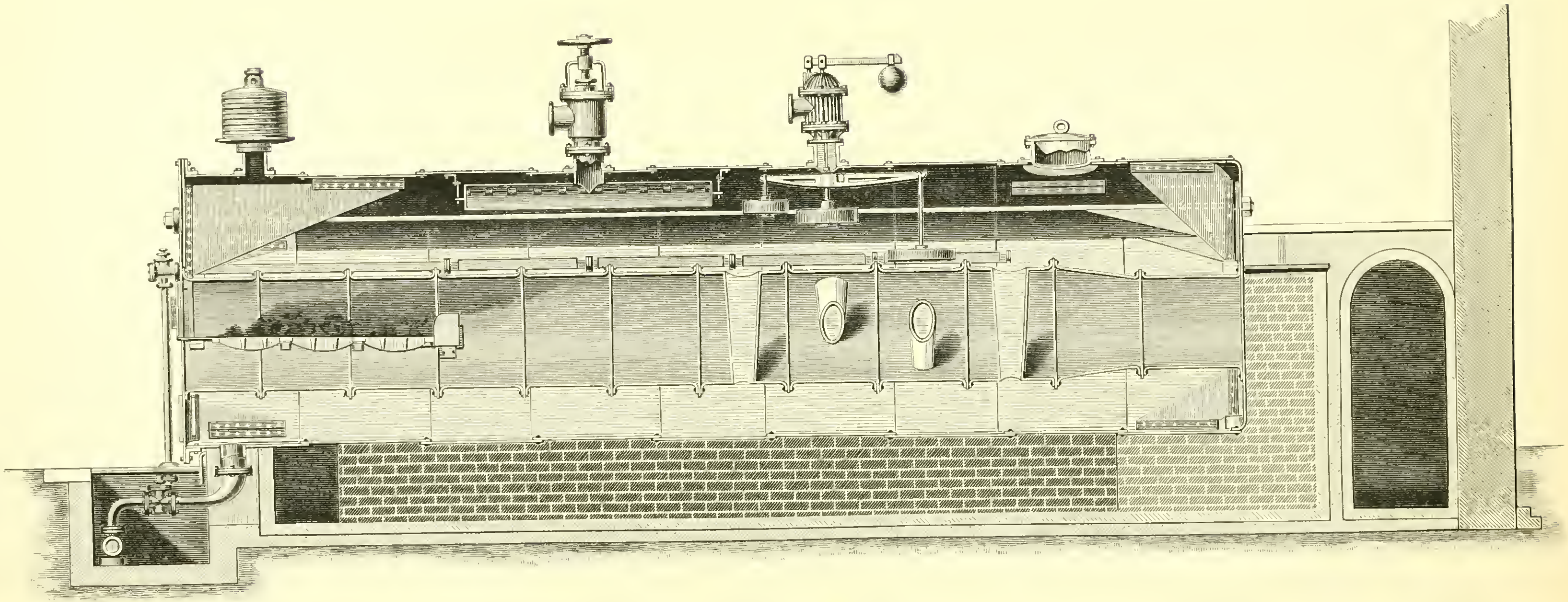


Fig. 1. Lancashire Boiler.

Figs. 1 and 2 give views of a standard Lancashire boiler. Such a boiler is generally about 30′ long by 7′ 6″ in diameter. The two internal flues are about 3′ diameter, and the grates in them are generally 6′ long. Galloway or cross tubes, about 6″ diameter, are often placed in the tubes back of the bridge wall, five to each flue, but this is advised against by some of the best authorities. The gases, after leaving the furnace tubes, pass underneath the boiler to the front, then back along the sides to the underground flue. Such a boiler would have 36 sq. feet of grate surface and about 1,000 sq. ft. of heating surface, giving a surface ratio of 28. When built for 160 lbs. steam pressure, it costs about $2,500 in England, and will deliver easily 6,000 lbs. steam and more per hour. At this

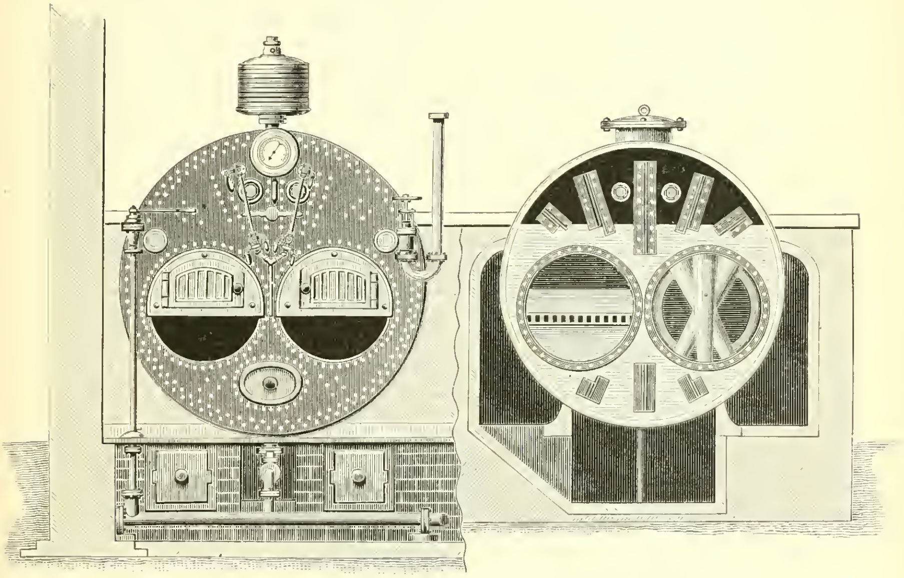


Fig. 2. Lancashire Boiler.

rate it is not very economical, but if used at a lower rate or in conjunction with an economizer it is as economical as any other type of boiler. It is a boiler that is very easy to keep clean, since every portion of the surface, inside and outside, is easy of access. It is considered as easy to keep from smoke as any other type of boiler, and it is also a very safe boiler, as is shown by Table II., also prepared by Mr. Hiller, showing the number of explosions per 100,000 boilers of various types in Great Britain and Ireland. In justice to the water tube boilers as they appear in the table, it should of course be said that, though the number of explosions may have been as great, the total damage must have been much less.

TABLE II.

BOILER EXPLOSIONS IN THE UNITED KINGDOM.

UNITED KINGDOM. TYPES OF BOILERS.	Average proportion of different types for 10 years—1885 1894.	Supposing total number of Boilers = 150,000 these proportions give totals of each kind as below.	Total Explosions 10 years—1885-1894.	Explosions per 100,000 per annum, equal relative rate of explosion.
Lancashire	38.3	57,450	33	5.75
Cornish	25.5	38,250	60	15.70
Vertical Fire-box	13.6	20,400	98	48.00
Locomotive	8.2	12,300	40	32.50
Plain Cylindrical	8.6	12,900	48	37.20
Water Tube	1.0	1,500	4	26.60
Rastrick	1.7	2,550	3	11.80
Other Types	3.1	4,650	35	
	100 0	150,000	321	

The Cornish boiler is exactly like the Lancashire except that it has only one furnace tube. In England this single tube is placed in the center. In Germany it is placed to one side with the idea of improving the circulation. It is nowadays rarely built, except for small plants, so that the average Cornish boiler is probably older than the average Lancashire. The Galloway boiler is generally classed as a Lancashire, which it resembles in every respect except that the two furnaces meet back of the bridge wall in a single large flue filled with Galloway tubes.

In France and in Elsass, Germany, the type of boiler known as the "elephant" is the standard. This is classed under the head of externally fired cylindrical in Mr. Hiller's table. It is not as regular in size or proportion as the Lancashire.

Fig. 3 gives an idea of the shape. The upper shell is generally from 20′ to 30′ long and some 5′ in diameter. The two lower shells, called "bouilleurs" are about 2′ diameter. They have one and sometimes two connections to the main shell. This boiler has the advantage of allowing a large grate surface, a great considera-

tion with the poor coals in use on the Continent, and is also very easy to clean. One difficulty may be in priming, as the water level was very irregular in such boilers as the writer saw, probably due to the contracted space for the exit of the steam formed in the bouilleurs.*

Occasionally fire tubes are placed in the upper shell, making the latter resemble an ordinary return tubular boiler.

For electric stations the water tube boilers were decidedly in favor. The two chief types were the Babcock & Wilcox type in England and the Heine type in Germany, the names referring to the general type and not necessarily to the firms making the boilers.

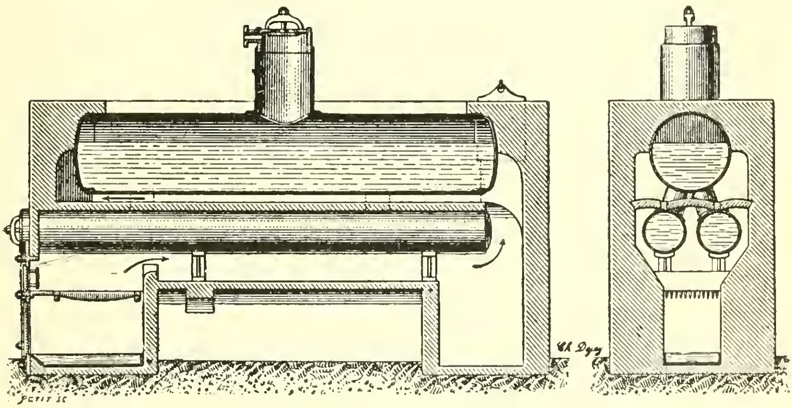


FIG. 3. ELEPHANT BOILER.

Of course, many other types were in limited use, plain cylinder, Scotch, etc., etc., besides almost as many forms of water tube boiler as have been invented in America. There were, however, two special types to which the writer wishes to call attention. The first, Fig. 4, is known as the dry back marine boiler and is in some use in England. It may be best described as a return tubular boiler with a pair of furnaces in, instead of under, the boiler.

The second, Fig. 5, is a compound boiler in use in Germany, composed of a return tubular boiler connected with a Lancashire boiler in such a way that the tubular acts as a steam separator for any priming in the Lancashire, and the connection between the two offers an overflow if there is too much water fed into the upper boiler. These types, particularly the first, seem to the writer as being especially adapted to future American practice unless the

*See also Proc. B. I. M. E., 1896, p. 169.

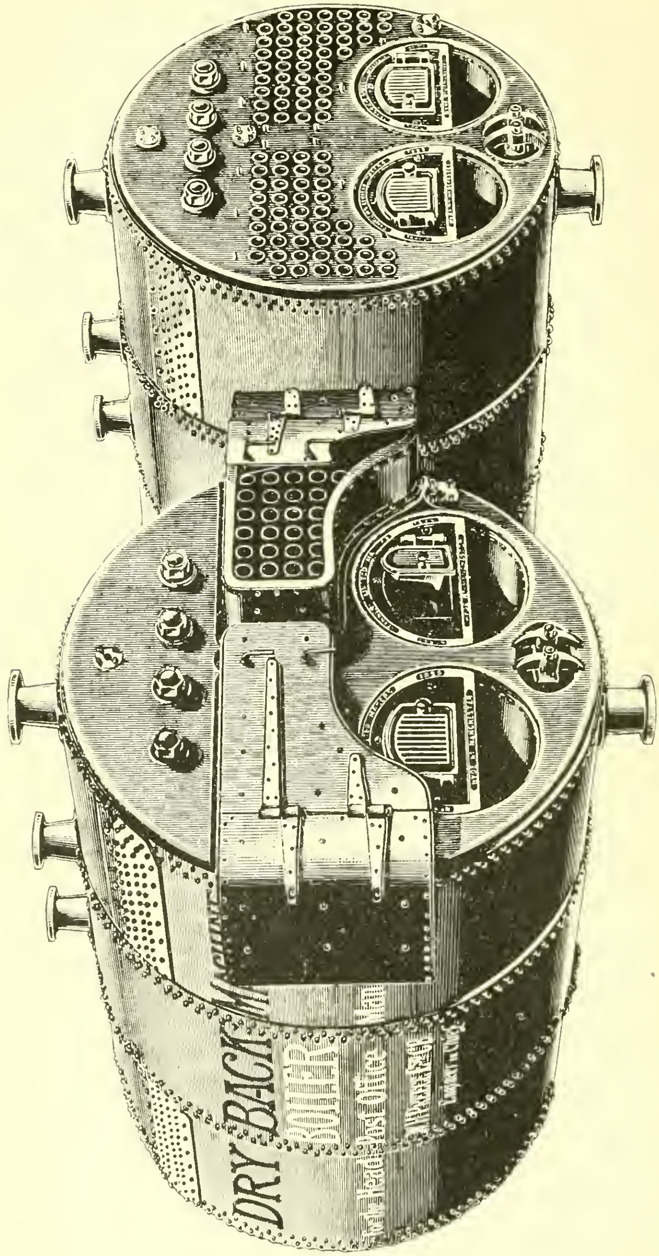


Fig. 4. Dry Back Marine Boilers.

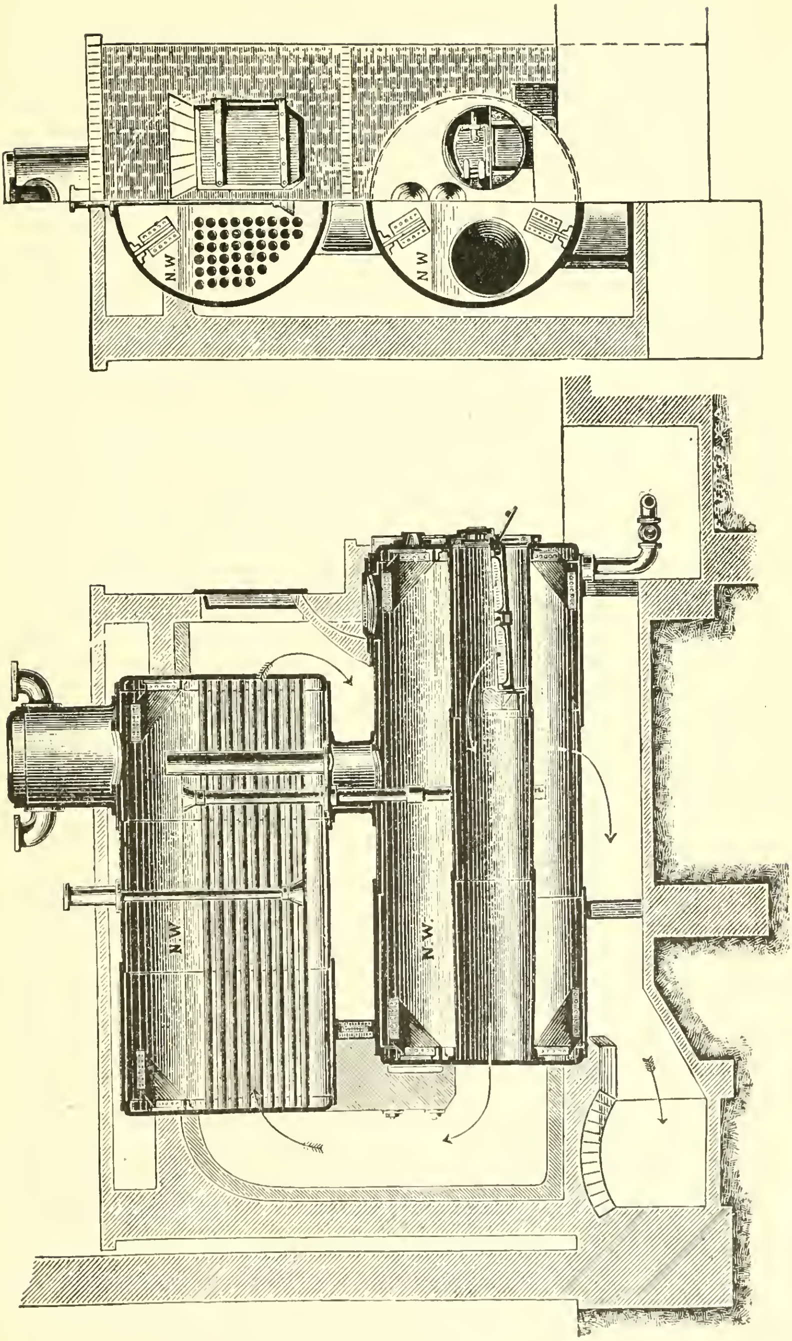


Fig. 5. Compound Boiler.

latter should turn to water tube boilers. These types, the marine dry back and the compound allow the very high pressures now in use on internally fired boilers while preserving many of the advantages of the horizontal return tubular.

In boiler construction I judged the English workmanship to be fully equal to our best. In England no punching is allowed; the plates are always planed on the edges and then drilled in place. Steel is being used almost exclusively in England; iron is still preferred in some places on the Continent. One English maker claimed that he did not need to caulk his joints. While this may have been an exaggeration it indicates the ideal they aim at. They generally figure on twenty years as the average life of a boiler, some running up to thirty and forty years at times.

The internal flues in the Lancashire boilers are generally welded along the longitudinal seam, and the cross or Galloway tubes are frequently welded in. I did not hear of any cases of welding the boiler-shell itself. The flues are occasionally made corrugated in various ways as the Fox, Purves, and other patents. My impression was that these were considered better, but that most frequently the improvement did not warrant the expense.

The steam pressures, of course, varied from the plant to plant. I should judge that if 140 to 150 pounds was considered a standard for a new mill in America, the corresponding practice would be 200 pounds in England, 180 in Elsass, and 140 to 150 in Belgium and Germany. In all countries I found occasionally higher pressures than the above, and, of course, the immense majority were lower. The above seems to me to be, however, a fair comparative statement.

ECONOMISERS.

The use of economisers is more general in Europe than in America, and the type known as the "Green," Fig. 6, now made by several good firms, is decidedly the standard. This consists of sets of vertical cast iron pipes about 10′ long and 4″ diameter, and is fairly well known in America. Occasionally on the Continent one of the bouilleurs of the elephant boiler was used as an economiser. The most general practice was to put one economiser for each battery of boilers, making the economiser heating surface and the boiler heating surface the same. In Belgium, however, they were recommending one small economiser to each boiler. Scrapers are almost invariably used to keep the fire surfaces clear of soot. The water surfaces are subject to scaling if the water be bad, and it is chiefly in the bad water districts that economisers are not used,

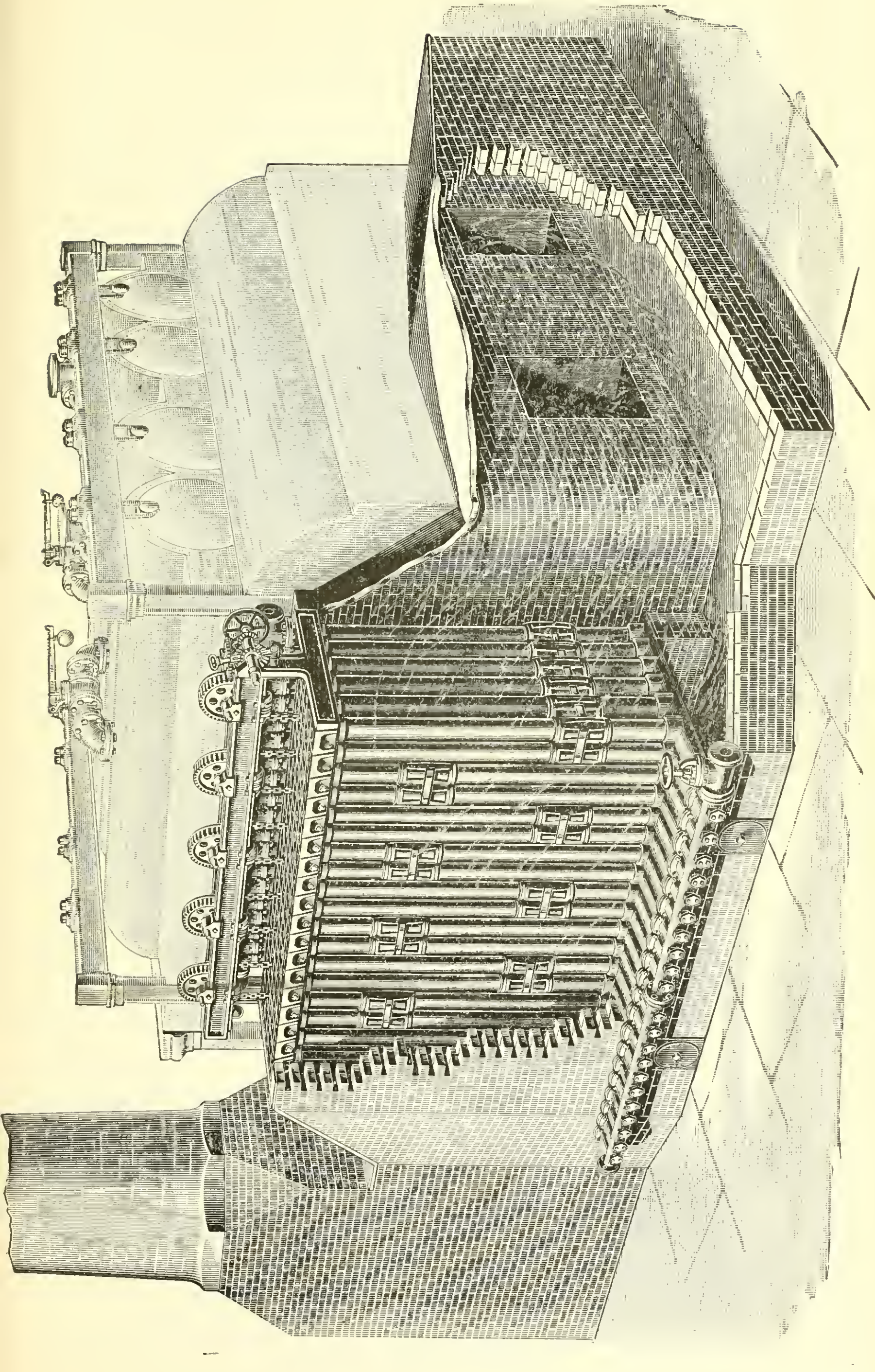


Fig. 6. Green Economiser.

though they are not much, if any, worse in this respect than water tube boilers. But when the economisers are taken out the heating surface of the boilers must be much increased to get the same economy.

An advantage claimed for the Lancashire boilers and for the economisers was that the large amount of hot water in them afforded a reserve of heat for a sudden call. An interesting application of this principle were the feed storage and the steam storage systems of D. Halpin, Esq., London. The first is applicable to all plants and consists in providing tanks in which the feed is heated to the steam temperature by steam from the boiler during light demand, so that during the heavy demand the feed water is supplied hot (360° F.) instead of 100° to 200°. The steam storage consists in having very high pressure boilers, which pressure is reduced at the engine. Water is heated to boiler pressure during light load and stored in tanks, and during the heavy load expands into steam and relieves the demand of the engines on the boilers proper. The steam storage system did not impress the writer favorably. If you are going to go to the expense of high pressure boilers anyway, then it seems to him that you will be as apt to save coal by using high pressure steam at your engines as by reducing the pressure in order to equalize the load on the boilers. But the feed storage system, particularly where economisers are not used, seems a very practical method of reducing the net first cost by a few per cent. (the boiler plant saved would often cost more than the feed storage), and at the same time probably increasing the economy. Both the feed and steam storage systems are especially available with bad water.

SUPERHEATERS.

The use of superheated steam is very much in the air all over Europe, and in Elsass (Alsace) it is fairly general, about 500 superheaters being in use. There has never been any doubt that it saved from 10 to 20 per cent. of steam and coal, but the difficulty has been in the lubrication of the engine cylinder and the keeping the large number of superheater joints tight. The Schwoerer superheater, which is so much used in Elsass, consists of a small number of very heavy ribbed cast-iron pipes placed in a very hot portion of the flue, as, for instance, between the tubes and the drum of a Babcock & Wilcox boiler. The cast iron is made thick enough so that it may become red-hot without injury, and by being in the hot portion of the flue only a small superheater is required. The trouble with lubrication is overcome by using a high grade

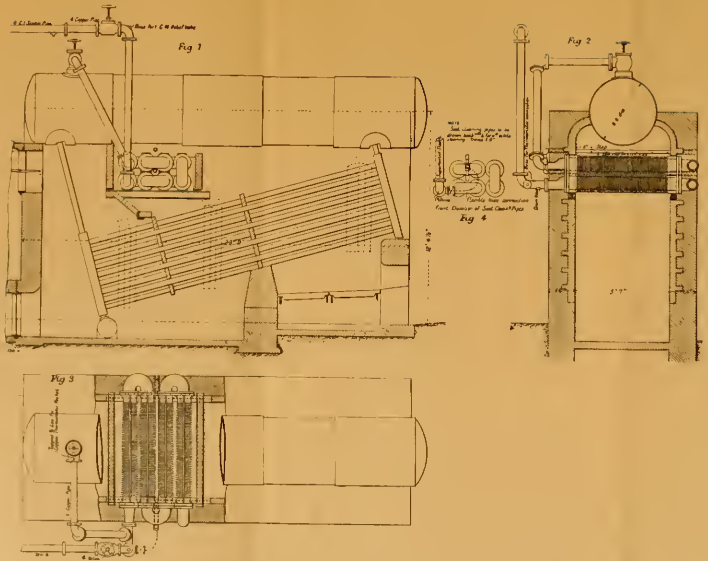


FIG. 7. SCHWOERER SUPERHEATER APPLIED TO BABCOCK & WILCOX BOILER.

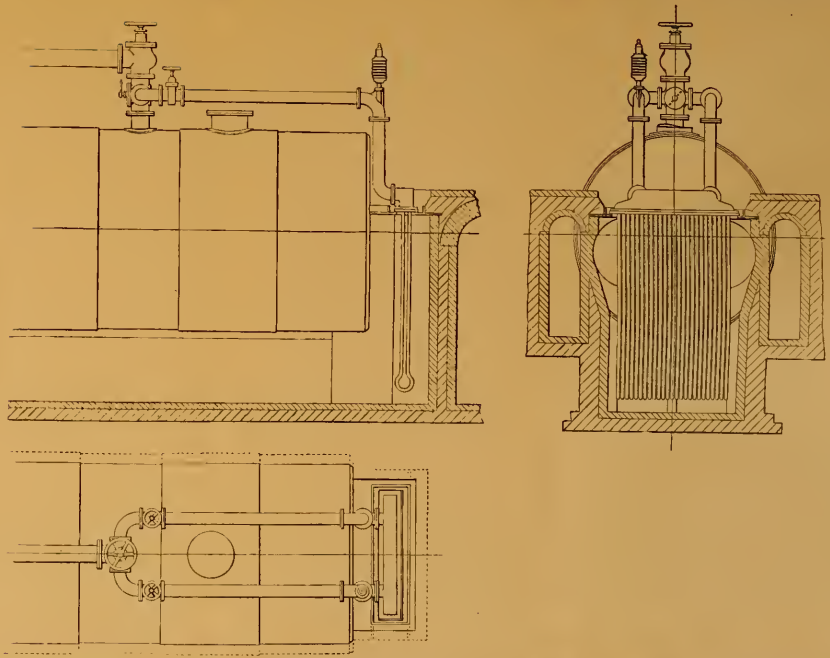


FIG. 8. STEEL PIPE SUPERHEATER APPLIED TO LANCASHIRE BOILER.

mineral oil. Fig. 7 shows a Schwoerer superheater in a Babcock & Wilcox boiler. In England and on the Continent, several forms of superheaters using thin steel pipes were under test. I did not hear of their sale in any number as yet. Fig. 8 shows one of these superheaters, made by Hick, Hargreaves & Co., applied to a Lancashire boiler. The superheaters are also placed above a separately fired furnace in some plants.

GRATES.

The grates in ordinary use did not noticeably differ from those in use in America. In Germany, some of the under-fired boilers were provided with grates that inclined downwards to the rear as much as a foot or a foot and a half, which was thought to be easier for the firemen and to give better combustion. The ash-pits of these boilers were unusually deep. The coal is frequently very soft and bituminous, but in their internally fired boilers they had no trouble from having the furnace top only 18″ or less from the grates, in fact, the Lancashire boiler enjoyed a better reputation for smokelessness than many others.

MECHANICAL STOKERS.

In England several forms of mechanical stokers were in use, perhaps over one quarter of the boilers being equipped. They may be divided into two general classes, the coking stokers and the sprinkling stokers. The coking stokers feed the coal at the front where it cokes and is then carried to the rear by the reciprocating motion of the grate bars. The Vicars stoker (Fig. 9) is the best known of the coking class. It is represented in this country by the Roney, Wilkinson, Murphy, Brightman and other types; the chief difference being that on account of the internally fired boilers the Vicars grate bars are level. The sprinkling stokers throw the coal over the grates by means of revolving or oscillating shovels; but they generally use as well a reciprocating motion of the grate bars to carry the ashes to the back end. The Bennis stoker is perhaps the most widely used of this class, but there are several good firms who make stokers of each class.

Opinion is, of course, widely divided on the merits of mechanical stokers. What seemed to the writer to be the general drift of opinion of those best fitted to judge, was as follows: No stoker absolutely prevented smoke, but both types very largely diminished it. In this respect the coking stoker had a decided advantage over the sprinkling.

Neither stoker kept up the steam pressure on a sudden call as

well as hand firing; in this respect the sprinkling stoker was considered to act more quickly than the coking.

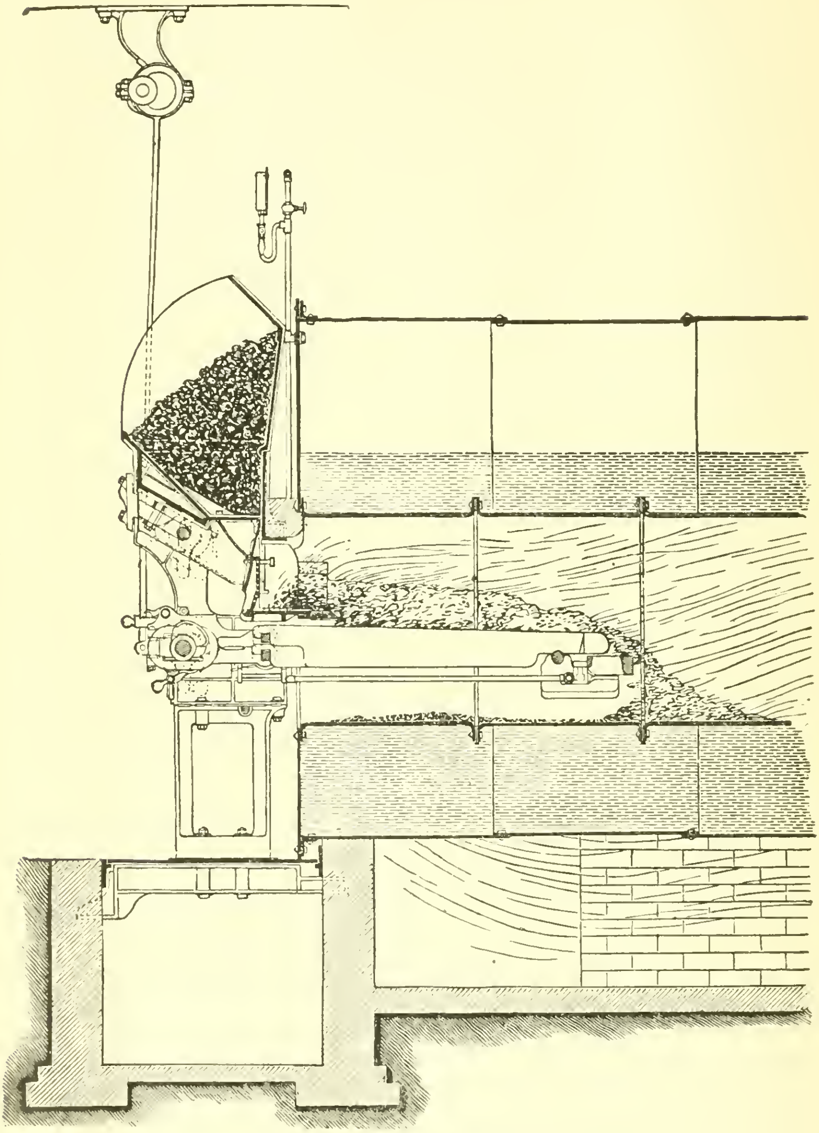


FIG. 9. VICARS MECHANICAL STOKER.

The sprinkling stoker was being sold at about three-quarters the price of the coking. The cost of the Vicars stoker was about $500 for two stokers, each 2′ 9″ or 3′ wide and 4′ or 5′ long.

The opinion as to whether the stokers saved coal was evenly divided. The most general reasons for their adoption were the diminution of smoke, the smoke laws being very strict in England, and the use of a cheaper fuel. The use of a cheaper fuel undoubtedly saved money, but when compared on the same grade of fuel the best opinion, so far as the writer could judge, was that they saved some coal, but not enough to show a net saving after paying the interest and repairs. The saving in labor was not generally considered and did not amount to very much in small plants, or in plants where no coal handling devices were adopted. The use of stokers and coal handling appliances together was thought to save about one-third of the boiler room labor in large plants.

In Germany grinding the coal to a powder and blowing this dust coal mixed with air into a hot combustion chamber was a method that was being experimented on in several plants and was meeting with considerable favor. The "Wegener" process is used in England; the "Camp," the "Schwartzkopf," and others in Germany. Fig. 10 shows one of these arrangements. The fine dust (almost as fine as flour) is, however, not only a very dirty stuff to handle but is also exceedingly liable to spontaneous combustion, and the problem of grinding and storing it had not yet been commercially solved so far as the observation of the writer went.

The admission of air above the fire either at the door or at the bridge was used occasionally. The opinion was very general that this diminished smoke. As to economy of coal, authorities were divided, but the general drift was, that this admission of air resulted in a slight loss.

BOILER FITTINGS.

In boiler fittings several differences were noted. All fittings were noticeably heavier and stronger than with us. The use of spring-loaded safety valves is looked on as yet with a great deal of distrust, and those in most common use are the lever valve and also the dead-weight valve. One form of the latter has the great advantage that it cannot by any possibility be tampered with while the boiler is under steam.

The use of try-cocks has been entirely given up in every plant that I visited and two gage-glasses are used instead, having been found not only neater but also safer. On the Continent one glass and a mechanical level indicator were sometimes used.

Last March one of our members had a great deal of trouble with his gage-glasses when using high pressure steam, and the Steam Users' Association suggested to him that he should try the

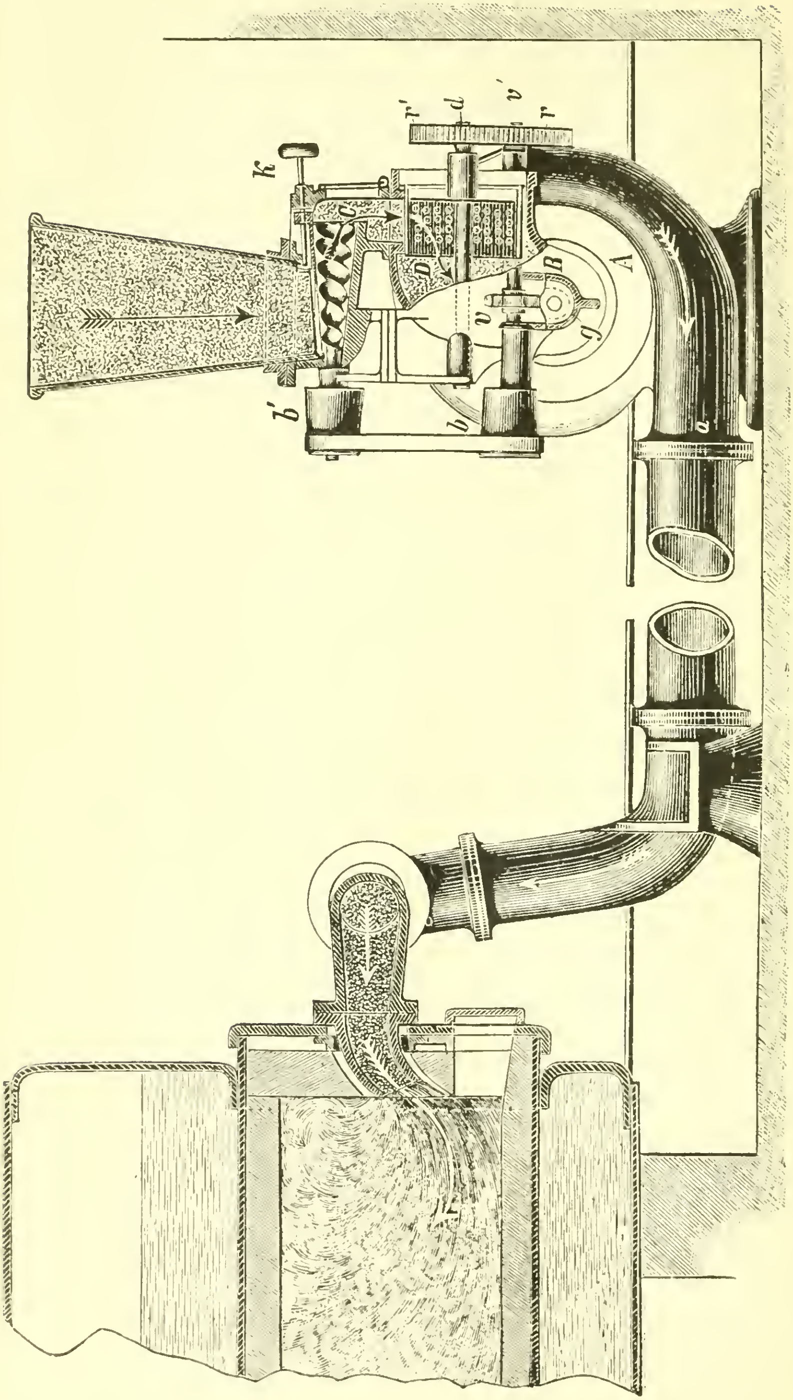


Fig. 10. Apparatus for Burning Powdered Coal. Patent F. de Camp.

new glass made at Jena by Schott & Genossen known as the "verbund" glass. This glass the writer finds to be coming into use very fast in Europe, especially for very high steam pressures. On his return, the writer was interested to know what the result had been during his absence with the Jena "verbund" glass. The report was that the single Jena glass was still in use, while during the same time two Scotch glasses had broken on each of the other boilers.

The dampers on the smoke flues are almost always of the sliding and not of the butterfly type. This may be because the flues are almost always underground. The dampers are always regulated by hand, damper regulators being practically unknown.*

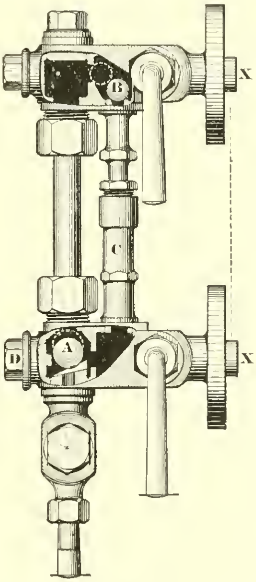


FIG. 11. PATENT GAGE GLASS BY HOPKINSON & CO., HUDDERSFIELD.

Forced, induced, steam-jet, and other artificial drafts are no more and no less in use than with us; that is they are not infrequent in special cases where the ordinary draft is insufficient, but they are in no sense general. A special boiler fitting that impressed the writer very favorably was a safety water gage-glass made by Hopkinson & Co., Huddersfield, shown in Fig. 11. The second connection shown back of the water glass allows the glass to be operated with no more trouble than the usual form, while providing absolutely

*I have since been informed that damper regulators are used to a certain extent in Lancashire, but I saw them in only one plant, and there the engineer spoke of them as a new thing.

against escape of steam or hot water into the fire-room when a glass breaks, and also against ever trapping a false water level, except by sealing up the connections or closing of cocks. This fitting is in very general use in the North of England, especially in cotton mills and mills of that class. The same firm makes a steam check-valve that is in fairly common use. The advantages of such a valve are well known, but none of the forms hitherto proposed have met with commercial success in this country. Another fitting of interest was the upward-opening balanced fire-door which was said to be easier for the firemen to handle and to protect him somewhat from the heat of the fire. This was in use on plants in London and at Paris.

The use of guards on the water-gages is very common to prevent pieces of broken glass from injuring the fireman. This is peculiarly necessary since in most of the foreign boilers the water glasses are on a level with the fireman's face.

PIPE COVERINGS.

The average quality of the boiler and pipe coverings did not seem to the writer as good as those in general use in this country. Occasionally he saw wood and even rope covering on high pressure piping, some of which was already distinctly charred. Some plants, of course, had very good coverings, and there was a custom of covering the top of the boilers very thickly with some cheap covering with the result that nine times out of ten the space over the boilers was noticeably cooler than it is in America.

CHIMNEYS.

In regard to chimneys the variety of sizes and of theories is just as great as it is here. The few of which the writer obtained both the dimensions and the amount of coal they were intended to burn were larger than those given in the tables in American books of reference for the same capacity. This may be because in England they lay a good deal of stress on a good draft as an aid in smoke prevention, and the English laws are very strict as to smoke. Brick is almost universal, iron stacks being used only in very exceptional cases. On the Continent many firms build their name or trade-mark into their chimneys in different colored brick, making an excellent advertisement. It is suggested that something of this sort might be required whenever any patent smoke preventing device be installed; in this case each would stand on its own merits and not on the merits of its salesmen.

BOILER OPERATION.

Whether as an effect or as a cause of the Lancashire and other types of boilers whose internal surfaces are so easily accessible, they seemed to keep these surfaces cleaner than is the general practice here. In some places they run the boilers until the specific gravity of the water is 1.005, then they blow out and clean the boiler. In England they use soda, lime, and potash in the boilers according to the impurities, and on the Continent they are also beginning to know about the advantages of kerosene. Purifying plants to take the impurities out before the water enters the boiler are not infrequent but are hardly considered a complete commercial success as yet. A little water is generally blown out once or twice a day just as with us and in mills the fires are banked at night. In electric stations the custom was very general to let the fires go out when they were not needed. The writer ascribes this difference not to the fact that a mill fire is out of use for less time (14 hrs.) than an electric station fire (16 hrs.), but to the fact that in the case of a mill the new fire must be started at say 4 A. M., when it would involve an extra shift of men, whereas in electric stations the new fire is needed at about 4 P. M. and involves no extra labor. Several plants gave us the result of experiments on the cost of banking fires. Reducing these to 24 hour days and to equal grate areas they run about 10 lbs. per 24 hours per square foot of grate.

The opinion as to the practice of letting the steam pressure off the pipes when the load was off was divided. On the whole it was in favor of the practice, although some plants said they had tried it and found the cost of repairs to more than balance the saving in coal.

BOILER TESTING.

Boiler testing is in some respects more advanced than it is with us chiefly in that they attempt to tell where all the heat supplied goes to and thus to determine the reasons of good or bad performances.

The bomb calorimeter in one or the other of its various forms, Mahlers, Donkins, etc., is considered the only accurate means of determining the heat value of a coal, though the method of analyzing coal and using one of the numerous modifications of Dulong's formula is quite often employed. The Thompson and other calorimeters of that type are not considered in the least available for practical work. It was the custom to correct the results of the calorimeter for the latent heat of the H_2O formed from the hydrogen in the coal, or, if using the formula, to assume that the hydro-

gen was burned to steam and not to water. Coal tests are, of course, compared on the evaporation per pound of coal, boiler tests were generally compared on the evaporation per pound of coal "pure and dry," dry referring, of course, to the moisture correction, pure to a correction of the earthy matter contained in the coal, but not allowing any correction for the unburned coal in the ashes. Occasionally, however, pure and dry meant exactly the same as our "combustible." In determining moisture in steam they are as far behind us in their general practice, with the exception of a few of their best engineers, as they are ahead of us in the analysis of the gases. Fortunately at the high steam pressures now in vogue the priming is generally a negligible quantity so that their results have not been affected.

In boiler economy I could not see that they were either ahead or behind us; they get from 60 per cent. to 80 per cent. of the heat in the coal according to the air supply and evaporation per square foot of heating surface. None of their engineers had ever found any combustible gases in the chimney except occasionally a little C O. (carbonic oxide). Most of their tests, however, left some zero to 15 per cent. of the heat unaccounted for, which may be radiation or error.* Some said one, some the other. No one had experimented as to why it is harder to supply the right amount of air to one kind of coal than to another, though they had all gone as far as to realize the immense importance of the air supply, as compared with any other factor in boiler economy, and also to realize and to experiment on the amount of air that leaks through the settings of some types of boilers to the injury of the economy. Frequently more air has been found to leak through the settings than came through the fire. In some plants on the Continent they were painting the brick settings with a heavy tar paint to make them air tight, and occasionally even enclosing them in sheet-iron casings. In Germany they have an instrument called the gas-balance which shows the per cent. of $C\,O_2$ (carbonic dioxide) in the flue gases on a dial like a steam gauge. If not too delicate it promises to be of great practical use.

The special instruments used for boiler testing besides those above spoken of were the ordinary thermometer for low flue temperatures, and for high temperatures, the electric resistance pyrometer, in England; the thermo electric pyrometer used in Ger-

*My own experiments point to a loss of from 2 per cent. to 10 per cent. by hydrocarbon in the gases, but since this would be caused by only 1-50 to 2-10 per cent. of the hydrocarbons, it would not appear in any volumetric analysis unless very carefully made. R. S. H.

many, and the mercury thermometer with compressed nitrogen or carbonic acid over the mercury, reading to 550° C. (about 1000° F. English measure). For analyzing flue gases the Orsat apparatus is most commonly used. (Fig. 12.) For getting the moisture in the steam the salt test is the usual one if the determination is made at all.

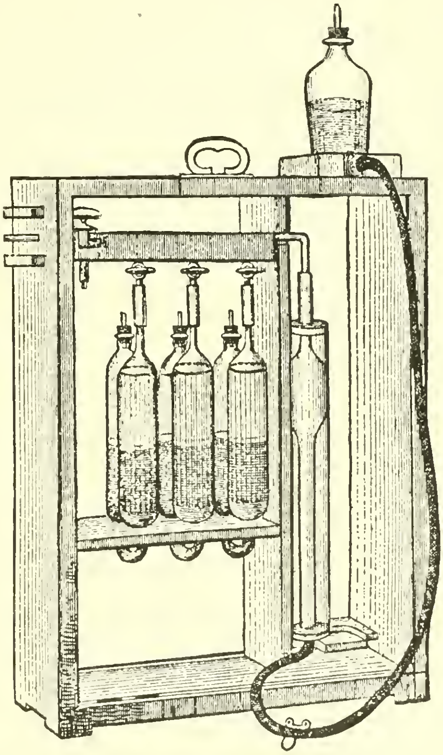


FIG. 12. ORSAT APPARATUS FOR GAS ANALYSIS.

Water meters are occasionally used on boiler tests, just as they are here by engineers sufficiently advanced to understand the precautions necessary in their use. I also found them in use occasionally to measure the water used during regular running; the cold water meters are, as in America, quite reliable, but the hot water meters are not considered as trustworthy as is desired. The two forms in general use in England are the Schonheyder and the Kennedy. Both are positive action meters; the Kennedy, Fig. 13, carries a rack on a piston rod and integrates the total length of stroke. The Schonheyder meter, Fig. 14, allows a sort of tipping, rolling motion in the upper piece shown in the figure, which is the

valve. This motion covers and uncovers the ports on the spherical seat, and the amount of water is controlled by the size of the

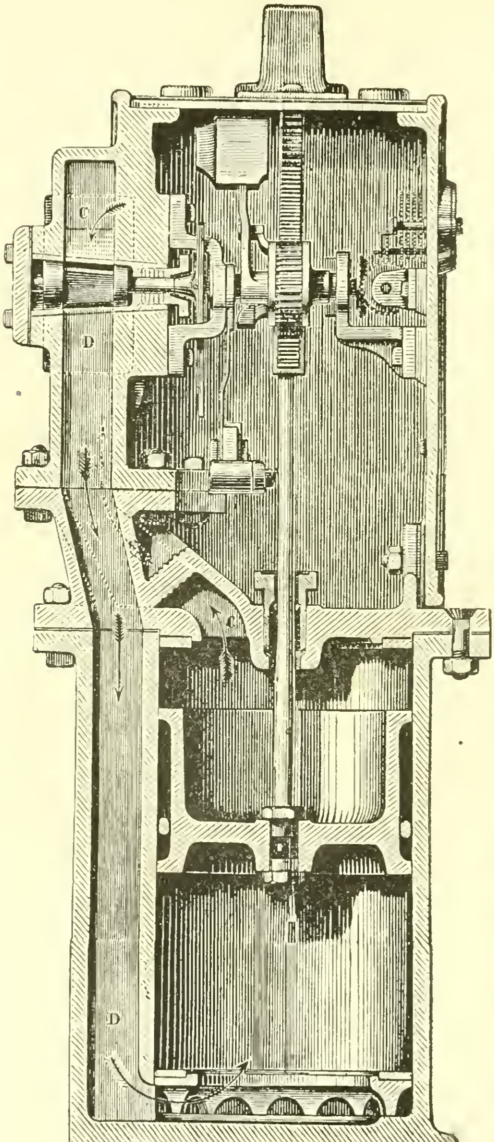


Fig. 13. Kennedy Water Meter.

pistons. Both meters enjoy a better reputation in England than any other hot water meter and than any hot water meter does in

America. Those who ventured an opinion as to their accuracy after extended use stated that they would trust them to about five per cent. after a year's use.

LABOR IN BOILER ROOM.

On the cost of firing, the writer obtained very little accurate information, but he judged the amount of coal per man to be fully as much in England and rather less on the Continent than in America. Part of the English excellence he ascribes to the fact

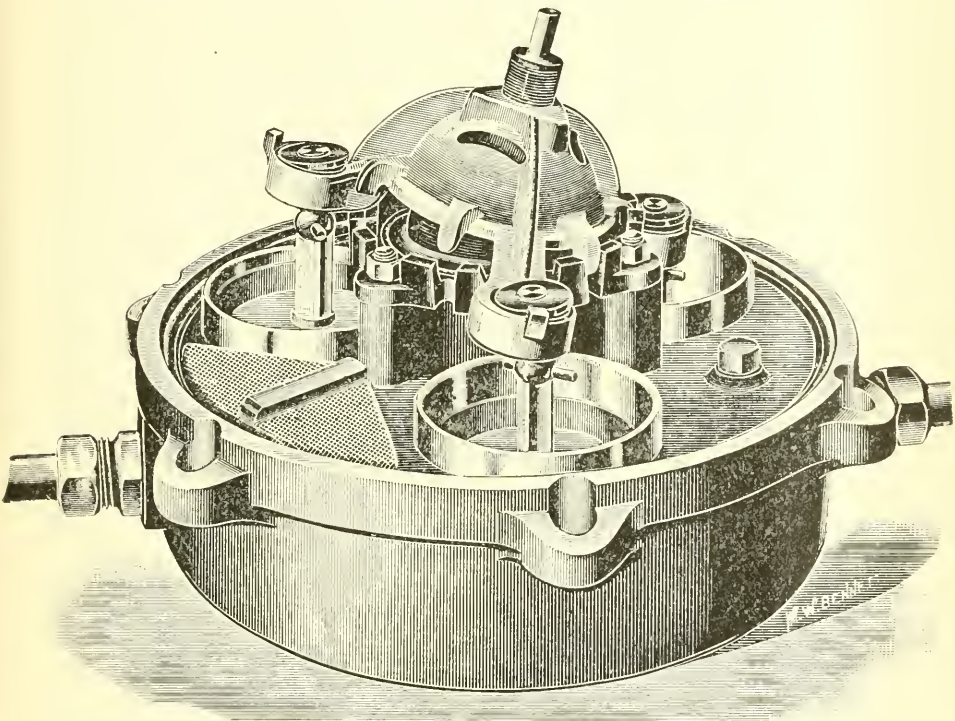


FIG. 14. SCHONHEYDER WATER METER.

that steam plants of all kinds are apparently more often built at once of the final size and are therefore better arranged for the work to be done. If an owner desires to increase his production he is more apt to wait until he can build a second full size mill than he is to allow the first to grow by small accretions.

The wages seem to run about, for firemen,—

$1.10	per	day,	England.
.80	"	"	France.
.87	"	"	Germany.
.80	"	"	Belgium.

MISCELLANEOUS—COST OF COAL.

The cost of coal of course varies largely from time to time. Nevertheless, with this proviso, a few figures may be of interest. In London, best Welsh coal, which is a smokeless, semi-anthracite of as high heating power as our best Cumberland, costs about $4.50 a ton; nut size Welsh coal, about $3.75. In the cotton district (Lancashire) soft coal, lying in value between say Clearfield and Nova Scotia, costs about $1.50 a ton. In Paris, Welsh coal is about $4.50. In Westphalia, the German manufacturing district, coal about equal to the English North Country (Lancashire, etc.) coal, is about $2.50 to $3.00. In Belgium, coal equal to Welsh was about $2.50. These are possibly inaccurate figures and only give a rough idea.

Briquettes of various sizes made from carbon and pitch are in use on the Continent for railways and steamers, and also for household use. They cost more than run of mine coal and were not used much in stationary practice except as a reserve. They are more easily and safely stored and handled than ordinary coal.

STEAM USERS' ASSOCIATIONS AND BOILER INSURANCE COMPANIES.

In England there are some half dozen of these, of which the Manchester Steam Users' Association is the oldest, and though by no means the largest it still holds, in many ways, the most influential position. It started solely as an inspection company, and on the mutual principle, but the advent of some of the boiler insurance companies forced it to give a guarantee that its inspection was sufficient to the extent at first of $2,500 and now of $5,000. It has the proud distinction that it has never lost a life from the explosion of any boiler guaranteed by it. Its charges are about $8 per boiler per year, for three annual inspections, one at least of which is entire. Besides the inspection and guaranteeing of the boilers the Association also inspects, indicates, and reports on steam engines, but without guarantee, the charges being from $8 to $13 per engine, according to the number of cylinders. The Association also inspects boilers during construction, and gives advice and draws up specifications for new plants, for all of which special charges are made; but being a mutual association any profit of any sort inures to the benefit of all the members. The other associations and insurance companies inspect and insure boilers generally at a somewhat less rate per boiler than the Manchester Steam Users'; they all inspect, and some of them also insure engines, and they all do the consulting engineering work spoken of above for new boilers or new steam plants.

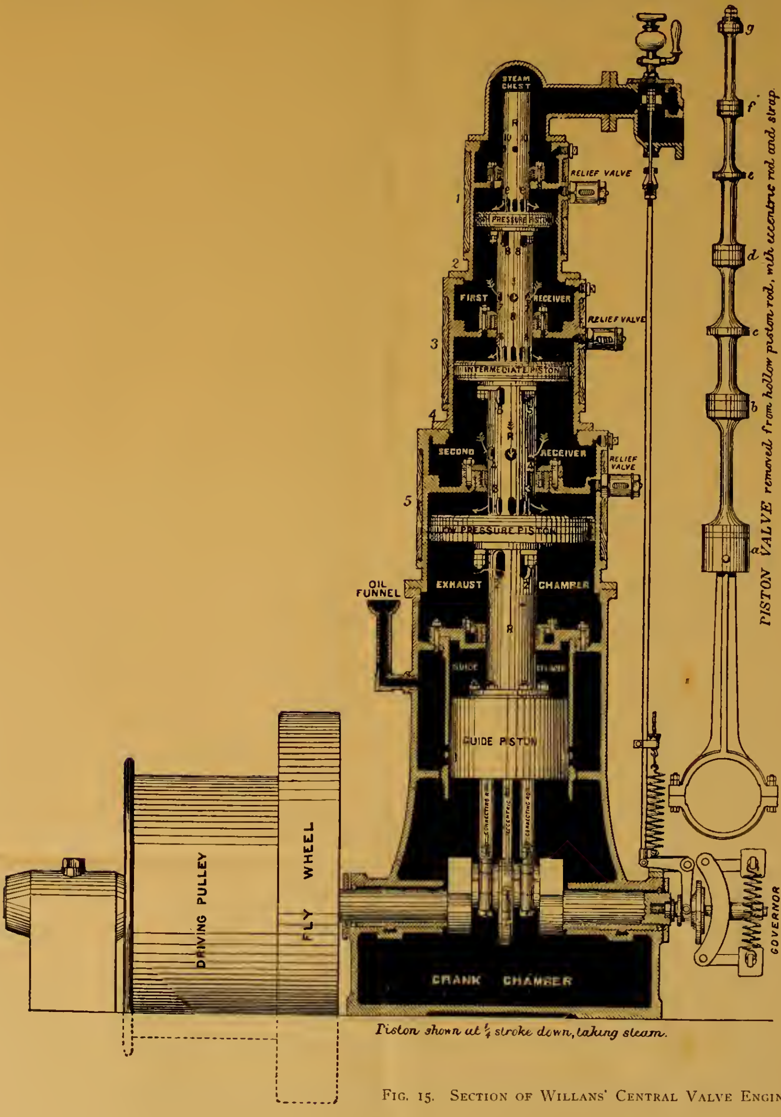


FIG. 15. SECTION OF WILLANS' CENTRAL VALVE ENGINE.

There is no law in England requiring boilers to be insured, but Mr. Hiller, in the paper above referred to, estimates that there are about 150,000 boilers in use, and some figures in the organ of the union of German boiler insurance companies for July 1 show that about 67,500 of these are insured in seven companies.

In Belgium all boilers must, by law, be inspected once a year. The chief organization for this purpose is the Association pour la Surveillance des Chaudieres a Vapeur, which does no insurance, but only inspects and advises its members as to the safety of their boilers, and also advises as to new plants, etc. It was stated to the writer that the law required only a certificate of inspection without inquiring as to the standing of the engineer who signed it, and that in this way the association was liable to a good deal of competition from small irresponsible associations and engineers.

In France and in Germany there are in each some 15 to 30 associations similar to the Belgian, which inspect boilers and give advice on all points connected with the steam plant, but which do not insure. These associations the writer understood to be recognized by the state, which required an annual examination to be made either by one of these companies or by the state agents. The most famous of all of these is perhaps the one in Elsass, at Mulhausen, but the writer understood that each confines itself to its own district, so that there is no competition, and that each is mutual in principle, so that there is no opportunity for any one to make undue profit. Their charges are about $7 per boiler per year.

STEAM ENGINES.

Although not directly a part of the writer's mission, yet he judged it profitable to pay some attention to the steam engines in use. They are practically just the same as with us, the high speed type being used occasionally for small work, but the Corliss almost exclusively for large mills. The Willans high speed single acting engine, Fig. 15, enjoys great favor in England for electric work, but the writer ascribed this more to the careful workmanship and design of special parts rather than to the general type. It is very compact, economical, and easily kept in order, as built in England. The vertical engine is coming in very fast for mill work, and a patent vertical engine, built by J. Musgrave & Sons, with one crank for two cylinders side by side, is meeting with some favor (Fig. 16). It is as economical as an ordinary engine, nearly as simple in operation, and of less first cost. It is known as the n. d. c. (non dead center) engine.

Steam Turbines are also appearing in large numbers in electric stations and occasionally for other work. They are far cheaper than a crank engine of the same size, but use from 40 per cent. to 100 per cent. more steam than good steam engines with

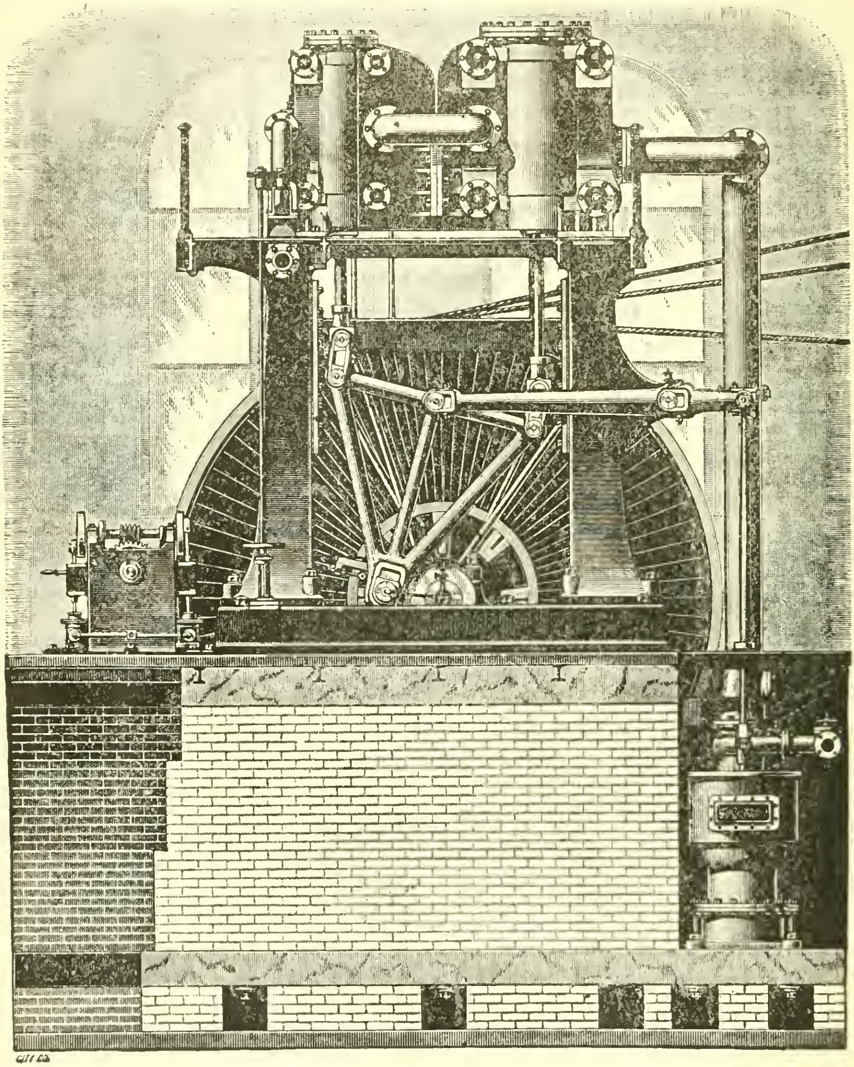


FIG. 16. N. D. C. (NON DEAD CENTRE) ENGINE AS BUILT BY J. MUSGRAVE AND SONS.

the same pressure and vacuum. Claims were made in some cases of better results, and if correct will probably be published before long.

MILL DRIVING.

The question of rope, belt, or gear driving for a mill is still farther from the writer's direct mission, but may be admitted. The balance of advantages seemed to be considered as follows:—

1. Ropes and belts take more power. Gears save 10 per cent.

2. Ropes and belts are quiet. Gears are very noisy.

3. Gears and belts are a little more complicated to install than ropes.

4. Belts give more fire hazard than either ropes or gears.

5. Ropes offer almost an entire security against shut down.

(This refers to the system of several independent ropes. The continuous rope system is not used.)

Belts cause more shut-downs than gears, but a break of a gear is a more serious matter.

6. Belts need least care in attendance, gears next, and ropes need most. If cotton ropes are kept well dressed and are not allowed to get too dry, they last about 12 years.

For these reasons belts have almost entirely gone out. I saw only one large belt in English mills and but few on the Continent. The English belt was thirty years old. Ropes are decidedly more in favor than gears.

For electric work direct driving is now nearly universal.

DISCUSSION.

Mr. Chas. T. Main.—The chief difference between English and American land practice is that in English practice the gases pass in large volumes along large areas of heating surface, while in American practice the heating surface is divided up into many smaller surfaces, the gases are broken up into small currents and the heat is more quickly absorbed. This accounts for the better results obtained from the boilers alone in America than in England, and also explains why economisers are used so largely in England.

A good example of English practice may be seen at the Lower Pacific Mills, where, in 1887, a battery of eleven Galloway boilers, 7 feet diameter by 28 feet long was installed, which were built by the Edge Moor Iron Company. Until the firemen had learned how to fire these boilers, poor results for capacity and efficiency were obtained. The method of firing was very different from that of the horizontal tubular boilers to which they were accustomed. In the horizontal tubular, the grates being so much larger, relatively to the heating surface, the rate of combustion was

slower and the fires required less care and attention. With the Galloway boiler the fires require constant attention if the boilers are doing a fair amount of work. After the firemen became accustomed to their work, better results were obtained.

A series of tests were made on these boilers by Mr. Comly, then engineer for the Edge Moor Iron Company, the boilers being fired by skilled firemen from the Edge Moor Company.

The average of twelve tests made under various conditions from May 7 to June 7, 1888, showed an evaporation of 11.40 lbs. of water per pound of combustible from and at 212°, and an evaporation of 7736 lbs. of water per boiler per hour from and at 212°. No allowance was made for superheating in the above results, which was given in two of the tests as averaging 21.5°, and the allowance for moisture in the coal was made by deducting it from the weight of wet coal, thus making no allowance for the evaporation of the same. The average percentage of moisture in the coal was 2.4. The temperature of the escaping gases was about 600°. The height of chimney above grates was 215 feet.

Mr. Barrus made two tests on the boilers in February, 1888, in which he obtained very poor results. These tests were made on a battery of six boilers, the results being 10.00 and 8.32 lbs. of water per pound of combustible from and at 212°. On June 7, 1888, Mr. Barrus and Mr. Comly made a joint test and obtained 11.07 lbs. with an evaporation of 7917 lbs. an hour, all from and at 212°.

In order to make the plant come up to our expectations when capacity and economy were combined it was decided that an economiser was necessary, and a Green economiser of 960 pipes was installed.

The average rise in temperature of the feed due to the economiser was about 140°, showing a direct saving of about 14 per cent.

The combined plant of boilers and economiser I consider an economical plant as far as evaporation is concerned, and the boilers are easily taken care of and can be thoroughly examined and should last many years.

The first cost of the boilers and setting and economiser, not including the flues, chimney and boiler house, was about $22 per H.P., the power used in getting the price being the average horsepower developed during the tests. A cheaper plant might have been installed which would have given as good or better commercial results.

We have reached about the limit of efficiency in the steam engine, according to our present knowledge, and the only thing which gives promise of greater economy is the use of superheated steam. The saving due to its use has been known for a long time, but the great drawback to its use has been the lack of a cylinder oil which would stand the high temperature of the steam. High grade oils are now obtainable, which can be used, and the danger of cutting the cylinders can now be overcome.

The object of superheating is to supply the steam to the engine at such a temperature above that of saturated steam that it can give up heat to the metal of the cylinder on admission without being lowered enough to reach the point of saturated steam. It can be carried high enough to prevent any condensation in the cylinder, this amount varying with the ratio of expansion, but if the amount of superheating is less than that necessary to prevent condesation, it will diminish the initial condensation and therefore make a saving. This shows the desirability of using a boiler which has some superheating surface, even if a superheater itself is not installed.

The vertical engine for mill work seems to be coming into fashion. During the past year or so several have been installed, and several more have been contracted for.

With such large diameters of low pressure cylinders which are required in the larger engines, there has been a good deal of trouble from cutting of cylinders by the drag of the very heavy pistons. This difficulty is overcome in the vertical engine. Other advantages are less space occupied on the ground, which is often a serious consideration, and a less amount of lost work in the friction of the engine itself.

In several instances the engine is connected directly to the jack-shaft, thus saving the loss in transmission from the engine to the jack-shaft. Four examples of this sort may soon be seen. One is now running at the Amoskeag Manufacturing Company, in the Jefferson Mill, one at the Atlantic Cotton Mills, one is being installed at the Washington Mills Company, and one has been contracted for by the Nashua Manufacturing Company.

The conclusions of the Englishman regarding the use of gears, ropes or belts on prime movers, it seems to me are wrong.

In many cases it is necessary to use gears, but where some other method of transmission is possible, it is well to avoid them. Ropes are used more or less in this country, and in some instances they are the only thing which can be used, but they give more or

less trouble. In my experience I have found nothing which gives such good results in the long run as a good, oak-tanned leather belt, if it is put in large enough to transmit its load without stretching the life out of it. If not overloaded, and if properly cared for, the life of a belt is a great many years.

Mr. George H. Barrus.—I am somewhat familiar with the subject of the paper, having read the author's report to the Steam Users' Association, giving an account of his European trip and the observations which he made thereon, and I wish to congratulate the society on being able to learn, through an eye-witness who has made so recent an investigation of the matter, what is actually going on at the present day in the line of steam engineering in Europe, and by a gentleman who is so painstaking and able to handle the subject as the author of the paper.

It is difficult to discuss a subject which has such a wide scope, and which touches so many details of construction and operation. I wish to refer to only two points which Mr. Hale brings out.

One of these is the matter of superheating. From the fact that superheaters are used to quite an extent in some parts of Europe, we might infer that American practice is behind the times in this special feature. I have no doubt that the practice of superheating has effected a saving, as Mr. Hale states, of 10 to 20 per cent., but there is serious question whether the conclusion can be drawn that the saving can be attributed entirely to superheating, or that we could obtain a similar degree of efficiency by adopting the same practices here. In some of the instances where the superheaters have been applied and tests have been recorded showing the performance the conditions have been such that the boilers have been overworked, and an excessive amount of heat has escaped to the chimney. In these cases the addition of the superheating surface was simply another method of increasing the evaporating surface of the boiler, and much of the saving has been due to the recovery of heat which would otherwise have been lost. It is hardly fair to attribute to superheating alone the economy which results in such instances. Perhaps Mr. Hale can enlighten the society with more particulars in regard to this matter, and say how far the advantages of superheating have been enhanced by the defective boilers to which the superheaters have been applied.

Some years ago I attached a Bulkley superheater to a horizontal return tubular boiler where the flue temperature was not over 400° Fahr., and I found that the saving of coal due to running a simple non-condensing engine was a trifle less than 7 per cent.

In this case all the heat which went into the superheater was at the expense of that which would otherwise have gone into the boiler, and the resulting advantage was due simply to the economy of steam at the engine which the superheating produced.

Another thing is the method of boiler-testing which is carried on in Europe, and in this I believe we can all learn something which it is profitable to copy. I refer to the practice of making an account, so to speak, with the total heat of combustion of the coal, and showing what part of it goes into the boiler and is utilized in evaporation, and what portion is lost through the various avenues of waste. It has not been very common with our engineers to do this, but we almost always see these matters fully treated in the reports of boiler tests which come to us from abroad. We have not been much in the habit of analyzing the flue gases and determining how thoroughly the combustion has occurred in the furnace. It seems a very rational method of treating this most important subject of the burning of coal, first, to ascertain how much heat can be derived from the combustion if it is carried on so as to be complete, and all the heat is recovered; then to find how much of this heat is utilized in making steam, and, finally, to trace out for the balance of the heat, or that not utilized, the various losses which occur, whether from excessive air supply, unconsumed gas, radiation, or other causes. This is the only way in which the question can be studied scientifically, and it is about the only way to obtain information which shall be a guide in realizing maximum efficiency. I am glad to say that there is a tendency to go into these questions more fully than we have in the past, and I think that in copying the English practice material advance may be expected in the improvement of American boilers.

Professor I. N. Hollis.—The means of communication between Europe and America is so easy and the interchange of data through the scientific periodicals so frequent that a visitor abroad necessarily finds some difficulty in presenting information not already well known. Mr. Hale has managed to cover the subject very well, and the society is indebted to him for a very interesting paper. The differences between European and American practice are likely to spring from surrounding conditions rather than from sentiment, and it is, therefore, not the best policy to change our practice because the English have found something else better. The great variety of conditions and coal render anything like a standard in boiler practice extremely difficult in the United States. In fact, we have not yet developed a method of testing which en-

ables us to compare accurately the efficiency of two boilers. The differences between firemen are often greater than those between coals. Any one who has had to maintain speed and power during a shift of firemen has come to a realizing sense of this. We must eliminate the man entirely, if our comparisons are to have a high value. So far, the personal equation of the fireman has not been obtained.

Mr. Hale has done well in calling our attention to the analysis of gas collected from the chimney. This method bids fair to solve the combustion problem. With a quick method of analysis, or some instrument to indicate the specific gravity of the combustion products, we can ascertain at once the evidence of imperfect combustion, or the presence of oxygen in excess. I think the latter will usually be found to be the case, and I have never yet detected any evidence of carbon monoxide in the chimney. The fireman who succeeds in producing it should be apprenticed to some other trade.

Superheated steam, the use of which has increased somewhat in Germany, deserves another trial in this country. Notwithstanding the numerous attempts to use it during the past thirty years, we have little data as to its behavior with the high-grade oils now manufactured. It is not certain that these oils will really prevent cutting without a thin film of moisture deposited on the rubbing surfaces. The oil cannot be distributed uniformly unless it be condensed upon the cylinder walls with the steam or from its own vapor. We all know that moisture does not go with superheated steam.

Mr. R. S. Hale.—Mr. Barrus raises a very interesting and vital point in the subject of superheating. So far as I could learn, superheating has shown a large gain in the amount of steam used per indicated horse power, a gain which is, of course, entirely independent of the efficiency with which that steam is produced. In addition, there is found, in many cases, a gain due to the improvement of the boiler efficiency, either by saving heat otherwise lost, or by other means; but I should understand that any serious claim to economy by the use of superheat referred to the economy in the use of steam, and not to economy in its generation. A point which should have been brought out in the paper is that the large saving in the amount of steam per horse power is due to a very large amount of superheat, temperatures of 600° to 700° F. being obtained.

My personal experience with carbon monoxide in the gases

from the boiler has not been so fortunate as Professor Hollis's, as I have only recently made tests in which the carbon monoxide reached several per cent.; for several hours on one test it was nearly 10 per cent., and this although the fireman was supposed to be something of a crack. I have very seldom failed to find carbonic monoxide when testing boilers with small combustion chambers, and with no provision for the admission of air above the fire.

TOPOGRAPHICAL SURVEYS OF THE METROPOLITAN PARK RESERVATIONS OF MASSACHUSETTS.

By Henry F. Bryant, Member of the Boston Society of Civil Engineers.

[Read before the Society, October 21, 1896.*]

The two great Park Reservations, the surveys of which are the subject of this paper, are the Blue Hills, lying in the southern portion of the Metropolitan district, and the Middlesex Fells, in the northern portion. I will not take space to indicate what the topographical features were that led to their being considered desirable for public purposes, as that can be better done by those who have most closely studied the æsthetic conditions of the case. Enough that the Metropolitan Park Commission, after much deliberation, took or purchased some 4,000 acres in the municipalities of Quincy, Milton, Braintree, and Canton, and some 3,000 acres in Malden, Melrose, Medford, Winchester, and Stoneham. Much of the property taken was very difficult of access, and, in order to open it up speedily for public uses, a large number of men were employed in reconstructing existing cartways or opening new routes, so that they should be passable for pleasure driving during the larger portion of the year.

Soon after this work was begun it was found desirable to have some general topographical map on which the proposed roads could be shown and the desirability of new routes studied. Accordingly a map was made showing all existing paths and roads, and, by shading, the general features of the surface. This map was based upon the outline and taking surveys of the reservations made by various surveyors and plotted on a scale of 500 feet to the inch. The roads and paths, together with the forestry features, were then located and plotted by means of a pocket compass and pacing. The plans of the two large reservations thus made were first published in the report of the commission for 1895.

Those who have not seen this method intelligently used would be surprised to find how accurately the work was done and to know that with almost no exception the resulting lithographs, on a scale of some 1,600 feet to the inch, were perfectly accurate when scaled, *i.e.*, no other method would have better served the scale.

*Manuscript received April 26, 1897.—Secretary, Ass'n of Eng. Socs.

BLUE HILLS RESERVATION

SECTION C-6

FRENCH, BRYANT & TAYLOR, TOPOGRAPHERS

Before this plan was completed, however, it became evident that the roads and other works under way were not being sufficiently studied in advance, and that the results were decidedly inferior to what was desired as a permanent development. Accordingly, the commission, acting under the advice of Messrs. Olmsted, Olmsted and Eliot, the landscape architects, determined to have accurate topographical surveys made, to enable the landscape architects to properly study the various questions to be considered.

The commission, at the time, had no engineering department, and depended on various outside parties to make necessary surveys, and since a considerable sum was involved by the work, it was determined to advertise for bids for the same. Some forty bids were received, varying from $25.00 per acre down to $0.60. As these figures may not have been generally known to the profession, and as they serve to indicate how opinions vary on such subjects, they are given below:—

	Blue Hills.	Middlesex Fells.		Blue Hills.	Middlesex Fells.
Bid No. 1........	$25.00	$20.00	Bid No. 21........	$4.74	$3.44
" " 2........	17.00	20.00	" " 22........	4.70	3.45
" " 3........	12.25	12.25	" " 23........	4.25	3.75
" " 4........	12.00	10.00	" " 24........	4.12	4.12
" " 5........	10.00	10.00	" " 25........	4.40	3.70
" " 6........	10.00	10.00	" " 26........	3.99	3.69
" " 7........	10.00	8.00	" " 27........	4.21	3.87
" " 8........	7.95	8.95	" " 28........	3.00	3.25
" " 9........	9.30	7.60	" " 29........	3.25	3.25
" " 10........	6.40	6.40	" " 30........	3.25	3.25
" " 11........	5.56	6.46	" " 31........	3.25	3.25
" " 12........	6.00	6.00	" " 32........	3.00	3.00
" " 13........	5.25	4.80	" " 33........	2.05	*
" " 14........	5.25	5.25	" " 34........	2.85	2.60
" " 15........	5.34	5.00	" " 35........	2.45	2.45
" " 16........	5.00	5.00	" " 36........	2.30	2.30
" " 17........	5.00	5.00	" " 37........	1.50	1.50
" " 18........	5.25	5.00	" " 38........	1.45	1.65
" " 19........	5.00	5.00	" " 39........	1.35	1.25
" " 20........	4.88	4.88	" " 40........	.60	.60

*Both reservations for $3.59.

The work was let to French and Bryant, of Brookline, with whom was associated Mr. Gordon H. Taylor, for $2.85 per acre for work in the Blue Hills, and $2.60 per acre for work in the Middlesex Fells.

It became apparent, soon after the bids were received, that it

was the desire of the commission to have the work completed within a year, and that they proposed to distribute the work among a number of surveyors to accomplish this. Since we had been approached by the commissioners, we at once filed a statement, showing that the only way in which the work could be well or speedily done was to give it all to one party. Triangulation work, bench leveling, and map finishing, in order to produce uniform and the best results, required that one party should conduct the work, for reasons apparent to any one who is familiar with such matters. We agreed to complete the work within fifteen months, the intention being to make use of two leafless seasons. The work was awarded and a start made in November, 1894, under the specifications of Messrs. Olmsted, Olmsted and Eliot, which I will not give in full, but which are briefly thus:—

SURVEYS.

The surveys are to be made sufficiently in detail to locate and put upon the maps the following information:—

1. The outline of the reservations, the boundary monuments, the monuments marking the city or town boundary lines, monuments or points established by the U. S. C. S. and the Massachusetts town boundary survey.

2. The roads along the limits of the reservation and those leading to or through the same.

3. All interior roads, wood roads or paths, all interior fences or walls, and all buildings.

4. Outlines of wooded areas and groups of trees and bushes, all large trees within these areas having trunks two feet or more in diameter, and all isolated or individual trees having trunks twelve inches or more in diameter.

5. The outline of all swamps and all water courses.

6. The outlines of all bold outcrops of ledge or rock.

7. Contour lines showing elevations of five feet apart.

The datum to which all elevations are to be referred is to be Boston base.

8. Stone monuments or iron bolts are to be set at the corners of each section, corresponding with the sectional maps, and midway between the corners on each section line running east and west.

The elevation of the top of these stone monuments or bolts above the datum is also to be accurately determined by levelling, so that these monuments or bolts shall serve as bench-marks for

any future work. Stone monuments and iron bolts will be furnished and set by the commission.

The section lines shall be accurately laid out and the interior portion may be filled in by *stadia or plane table work.* The error in horizontal distances in the position of the monuments shall in no case exceed twenty-five hundredths (0.25) of a foot in each section, and in vertical elevations of bench-marks the error shall not be more than five one-hundredths (0.05) of a foot in each one hundred feet of elevation. Contours are to be within one foot of the true elevations.

MAPS.

The map is to be drawn upon white paper, mounted on linen, and is to be plotted to a scale of 1 : 1,200 (100 feet to the inch).

The map is to be divided into sections, each section to include an area twenty-four hundred feet north and south by thirty-six hundred feet east and west, the true meridian being at the top of the sheet. A fine line is to be drawn showing the limit of each section, and the sheet is to have a margin of one and one-half inches all around outside this section line, and the number of the section is to be put upon the upper right-hand corner.

A complete set of accurate tracings made from the original sheets, and upon the best quality of Imperial tracing cloth from which blue or black process prints may be made, are to be furnished by the surveyor.

The sections are to be numbered consecutively, and a diagram is to be furnished by the surveyor showing each entire reservation on a scale of 1 : 12,000, upon which these sections are to be shown and numbered to correspond with the sheets.

The Blue Hill work was started first, and was placed under the immediate supervision of Mr. Taylor. A house was rented on the old Randolph turnpike, at the foot of Chickatawbut Hill, where the entire force employed on the work was boarded and housed. For the purpose of operating this house in a satisfactory manner, we advertised for a boarding-house keeper, with the result of having our office full of applicants for a week or more, taking a large share of our time, only to end in our giving the work to a married man already in our employ. The quarters were comfortable, but not elaborate, and the food of good quality and plentiful in amount.

I may as well say here that a large portion of such success as we obtained on this particular area was due to the use of a common dormitory and dining room, since the men in this way were

together evenings to talk over the work, and, as they were paid by the hour, the older men usually did more or less office work at that time, thus preventing all loss of time to the party, and also familiarizing themselves with the work of the next day. A heavy horse and wagon were purchased, and a team kept on each reservation to carry the men to and from the distant portions of the work so far as possible. At the Fells an office was rented at the Wyoming Station of the Boston and Maine Railroad, and the men were expected to find quarters in the neighborhood as they chose. For this reason they were not able, as a rule, to make the ten hours per day, so often made by the Blue Hills parties, and as a whole did not give so much time to evening work.

Soon after the contract was awarded us we were besieged by numerous applicants for positions, only a few of whom we were able to employ. We needed men having some experience in topographical work, but who were just entering upon their career, and therefore willing to take a moderate sum for their services until such time as they could be called expert. For the second man in the party we needed men of *some* experience, but not necessarily those whose judgment could be depended upon. The third man was usually an entirely inexperienced man of good health and habits, and industrious. I believe that all heads of parties and many of their assistants were graduates of some college or technical school, so you can readily see that the material was pretty good. The men to whom the special and more responsible work was given were all old and trusted employes of our office who could be depended upon.

The first work taken up was that of running the section lines called for in the specifications. Our suggestion had been accepted that a true east and west line should be laid off from the meridian passing through the State House in Boston, and from these two axes parallel lines should be run to form the sides of the sections which were 3,600 by 2,400 feet.

The Board of Harbor and Land Commissioners very kindly loaned us their eight-inch theodolite, made by Buff & Berger, and a start was made from the U.S.C. and G. Survey point on Big Blue Hill. A commanding point on Big Blue was determined on the east and west line 52,600 feet south of the State House and the section line laid off therefrom. This line passed over the tops of five of the high hills and was admirably situated to work from. We laid off and measuered this line as an experiment, as we all had considerable respect for tape work, but were not quite so familiar with the triangulation work, which we intended to use as an auxiliary.

Before we were far along with the section line mentioned, we realized that the work was difficult and expensive, and made a proposition to the commission to furnish them with triangulation points on all the leading summits determined with a greater degree of accuracy than that called for, together with section corners, determined within one foot, leaving out the intermediate points on the section lines, and also giving them an increased number of readily-accessible bench-marks, all in lieu of accurately placing the section corners and intermediate points. As this clearly gave a greater number of better and more useful points, with the section corners remaining just as valuable for the purposes for which they were intended, viz, scalework, the commissioners accepted our proposition, and only the one section line was run. This line was about three miles long, and when first tested by triangulation did not check within twenty-five feet or more. The method of measurement was that of driving plugs nearly flush in such position that the tape could be stretched straight from one to the other without the use of a plumb-bob. The elevations of the plugs were determined and the horizontal distances carefully computed. Great care was taken to check the levelling and measurements, the latter being taken four times under a definite pull, the readings being made by two persons. Yet with all this care twenty-five feet was the nearest we could make it to the correct figure. On going over the line again an error of from four to eight feet was discovered in several places, and the mistake was always in the feet and not in the fractions. One plug, at least, was also found where the same error of reading the rod had been twice made. After everything had been carefully gone over the measured distance and the triangulated one checked within four one-hundredths of a foot. We were satisfied that we *could* measure accurately, but that it was difficult and above all expensive. This line cost us nearly, if not quite, $500.00, and was not worth more than $50.00 to us when completed. I should mention that this work, like all the triangulation work, was performed during some of the severest winter weather of 1894 and 1895.

Triangulation work, both at the Hills and at the Fells, was begun at about the same time. At the Hills we made use of the Coast Survey value of a line from Big Blue to Wampatuck, which Mr. Van Orden, of the Massachusetts Topographical Survey Commission assures us is correct within one-half an inch. This was tested from several outside points, and we think that he is right.

At the Fells we found it very difficult to get a satisfactory base

as the two best points, viz, "Bear Hill" and "Dutton's Summer House" were invisible the one from the other. By using other points almost as good we managed to base our computations on the first two, only to find that we were nearly a foot out on our final measurement when checked on a measured base running from "Great Island," in Spot Pond, to "Duck Rock," a distance of half a mile. This base was measured with great care, using a U. S. C. and G. S. standardized tape over the ice again and again, and we were sure of its value. I am sorry we ever measured that base, as, but for doing so, we should never have discovered what seems to us to be errors either accumulated or individual in the points on which we depended. Of course, you naturally wonder whether our work was not the one in fault, but I think you will agree with us as to the accuracy when I say that our method of check was to deviate our triangles on either side of a given base, to finally locate some common point from the results of the various locations on each side, and the results were always within about one-tenth of a foot of each other. In addition to this we usually made each location from a third triangulation system, to eliminate, if possible, any error from coincidence. Again, on our work in the Fells, our triangles closed within an average of three seconds, if I remember aright, and if they overran five seconds, the case was investigated. This is much closer work than is generally done by the Massachusetts Survey or the Geological Survey, and is only possible in winter, I think. Our best work was done in March, when the instrument was set up in a tent, one man making the observations while the other got into the lee of some rock, to get warm and to be ready to take his turn, the thermometer varying from 32 degrees above to 10 degrees below zero Fah. You will readily imagine that there was but little boiling in the atmosphere with such temperature and with March winds.

After using the triangulating instrument mentioned, we found that the greater ease of manipulating the ordinary six-inch Buff & Berger full transit, No. 4, rendered the results taken with the latter instruments superior to those obtained by using the eight-inch instrument. Accordingly, after having three of our regular office transits, carefully repaired and adjusted in the shop, they were put on the work with very gratifying results.

Our signal poles were made of 3″x4″ fresh spruce joists, guyed with telephone wire. Some of the troublesome ones were wound with alternate strips of white and black cloth, flying white or black flags of various combinations. The ordinary method of placing was to drill a hole in the ledge about one inch deep, into

which a headless spike half driven into the axis of the pole was set, thus enabling the pole to be sighted for its full height, the bottom, of course, being always preferable.

After all angles had been taken they were tabulated and an arbitrary adjustment made with the system carefully plotted for examination. Here I am tempted to digress to express some views on the subject of adjustment by least squares and arithmetical mean as opposed to what might be called a common sense method. Least squares is doubtless the correct method in an extensive series, but cannot be used to good advantage in a case like this. Of course, after adjustment, all solutions or locations agreed, but to state it generally we believe that all our triangulation points in the two reservations are co-ordinated with a maximum error of one-tenth of a foot, assuming our base to be within that limit.

Almost simultaneously with beginning the work on triangulation a series of bench levels were run through the main roads of the two areas. At the Hills two independent parties brought levels from Hyde Park, which were supposed to be based on a very accurate bench, but, although the line was gone over four times, we do not feel that our bench at the base of Big Blue is within two or three-hundredths of a foot of the correct elevation. The trouble was caused entirely by the variation in length of the target rods used, the length changing with the weather. After spending a great deal of time in trying to obviate all these difficulties, we cast aside all target rods and made use of self-reading or speaking rods entirely.

The rod is a simple piece of 2″x1″ clear pine, twelve feet long, shod at both ends. This rod is used both for levelling and stadia, and all our men speak highly of it. With this rod, reading only to hundredths, the thousandths being estimated, a double line of levels was carried over the top of Big Blue to the other side and returned at the base with an error of 0.03 of a foot, while long lines of easy grades were run with errors considerably under one one-hundredth of a foot. Since our experience here with speaking rods we seldom use a target rod.

Spikes were placed in trees with a "Dennison tag" nailed or tied to the tree bearing the number of the point and its elevation, thus enabling plane-tablers to find their elevation anywhere without hunting for notes. By thus placing the tag, say four feet above the ground, a point could be very quickly found, even with heavy snow about.

After establishing certain triangulation points and benches,

we began the measurement of traverse lines, largely following existing roads and paths. When these were not sufficiently commanding, lines were run from summit to summit of the various hillocks encountered. This was done more toward the end of the work than in the beginning, and was more useful in the Fells than in the Hills on account of the smaller scale of the natural features in the former reservation.

We experimented at first with the use of the tape to feel sure that the cost of this method could not be brought somewhere near that of stadia work, but while experience would have doubtless enabled this method to have more nearly approached in cost that of the stadia work, the results were not enough better to warrant its use. For stadia purposes we had purchased four Gurley transits of simple centers, costing $147.00 each, I think, and one Reconnoissance transit of the same make, costing $115.00. These instruments all gave satisfaction, and, while far inferior to the Buff & Berger instruments, the results obtained with them were very good. They required more attention to keep them in adjustment than a higher grade tool would require, but were we to do the work again, I should favor their use.

The first stadia traverse of any size which was run in the Hills was about two miles in length and did not close by about ten feet. As an experiment, this was adjusted in the usual manner and various points incorporated in other traverses, only to find that they were all substantially correct as adjusted. The subsequent work was made to close within five feet in general, and usually closed much better.

After the Buff & Berger transits were released from the triangulation work and the men had obtained experience, Mr. Hunt, who had charge of the Fells work and made most of the later traverses personally, always expected, and usually realized, a closure of something less than one foot. Vertical angles and distances were read both ways and the elevations of the tops of the plugs deduced from these notes. I well remember my incredulity at a closure in the levels obtained in this way on the first long stadia traverse in the Fells. The two elevations of the starting point varied only two-tenths of a foot, and I felt sure it was either an error or a coincidence, as the line was nearly two miles long with great variations in grade. The work was done with a Buff & Berger instrument, which in part accounts for the result. This method, while followed thereafter, was not allowed to furnish level values until by repeated trials in both reservations and with all instruments it was demonstrated to be a trustworthy process;

but I confess I have never gotten over my doubts about it, and for that reason we undoubtedly did more actual levelling than was really required.

We began our first few traverses before we knew the co-ordinates of our triangulation points, and the lines were accordingly plotted on manilla paper, referred to some one line and pricked off on to the plane table sheets. These brown paper sheets gave us no end of trouble on account of shrinkage. We welcomed the method of State House co-ordination and applied it as soon as possible, with beneficial results to accuracy. The stadia points were usually plugs with nails and were marked by a tag on a near-by tree, bearing number and elevation, as in the case of benches.

The best and cheapest method of filling in between the traverse lines received not a little consideration at our hands. We recognized the *probable* superiority of the plane table at the outset, but, as we knew that various cross-section methods had been successfully used in other localities, they were very carefully considered before the plane-table method was adopted.

In the light of our present experience, I feel that the method that was used was the best one known, and in a few cases, where other methods have prevailed, I am sure that the efficiency would have been increased greatly by a final use of the plane table.

As called for by the specifications, mounted sheets of Whatmann's cold-pressed double-elephant paper were utilized for plane-table sheets. On these, six twelve-inch squares were drawn when the sheets were started, all plotting of co-ordinate values being from the nearest line thereafter, for the purpose of obviating, as far as possible, difficulties due to shrinkage.

There were some sixty sheets used, and the first eight had been mounted nearly two years, according to the dealer, while the other fifty-two were only a few months old. Contrary to our expectations, the ones which had been mounted for the longer period gave us the most trouble from expansion and contraction, the shrinkage being ten feet in 3,600 on some of the sheets. Exposure to sun and wind, and even to rain, for a month will cause any paper to shrink somewhat, but we found that by thoroughly heating and drying each sheet just before plotting the sections there was but little trouble thereafter.

The plane table party consisted of a chief, who directed the work and manipulated the table and sheet, with an assistant, who ran the transit and made computations where necessary, but whose main work was in the use of a cloth tape and hand level. One

rodman completed the party, and I wish I knew the number of miles walked by the whole force of rodmen during the survey. The figures would represent an enormous distance, I am sure.

The outfit was a Johnson plane-table movement, as first built for the U. S. Geological Survey, a Gurley alidade, with compass and levels, a speaking rod twelve feet long, a cloth tape, a stadia slide rule, a big umbrella and shoe, and, more valuable than anything else, a $5.00 brass hand-level of English make and of the Locke pattern.

The various heads of parties used methods which differed slightly from each other, partly on account of the variation in the ground itself and partly on account of the difference in the men. So far as consistent with good work, we allowed each man to follow his own course as to the details of his work. Some made constant use of a transit to carry a line of levels with the party, generally using it the same as a simple levelling instrument, but all used the method, in steep ground, of locating a point on a contour by a stadia reading and then taping the position of successive contours, measuring at right angles to the contour. A black tape was usually placed about the stadia rod at a reading equal to the height of the assistant's eye above the ground, and another at the contour interval of five feet above and below the same, thus enabling the quick sighting and placing of the rod through the small aperture of the hand-level. The first contour point was located, say from the alidade, a small square of pasteboard placed thereon; the assistant next plants his heel on the spot, and, standing upright, places the rodman on the same or next contour, and if the position last taken is not located direct from the plane table, he locates it by tape and calls the distance to the tabler. In this manner it was possible to run over country out of sight from the instrument, and more rapidly than could be done in any other way. The accuracy of the work was surprising, and, as far as possible, all lines were checked out to some known point. In somewhat level ground each contour was "chased" out, locating directly from the instrument.

At first, but little plane-table traversing was done; later, the results of this work proving so good, lines of 800 to 1,200 feet were carried on in this manner, with success.

In a few cases the ground was so shaped that signals were placed at several points which would come on the sheet, and their position located by intersection before the topography was obtained. By doing this, where the ground was higher along the borders of the sheet than in the interior, the topographer was en-

abled to locate himself anywhere by resection or to at least make certain of his orientation as no short or traverse sights could do.

The rate of work varied greatly, of course, with the ground surface, but was from two to twelve acres per day for each plane-table party, the latter amount being occasionally obtained in open country with few irregularities. The most difficult country was found in the southeastern portion of the Fells, where there were as many ledge outcrops requiring location and determination as there were contoured areas, and the surface was very uneven, while the most disagreeable country was portions of the Hills that had been swept by fire, leaving a close, stiff chapparal almost impenetrable without the aid of an axe, and not easily subdued by that.

No special adventures are to be recorded as occurring in either reservation, although we expected that there would be a few bad falls as a result of venturesome climbing in slippery weather. One man slipped on the ice in a fairly level spot and pretty badly banged a six-inch triangulation instrument, and one was badly poisoned by dog-wood, but the greatest excitement, perhaps, was occasioned by the sight and killing of rattle-snakes and copperheads in the Blue Hills. One man jumped a rattler, which he did not see until he was upon him, and, seizing a stadia rod, which was at hand, despatched his snakeship, bringing home the pieces of the rod along with the snake.

The sheets, after being made in the field by the topographer, were inked and traced, the finishing being done by one man, thus assuring uniformity in appearance. The finishing of each sheet and its tracing was the work of nearly a week, and some sheets required even more time.

The tracings were made with the intention of their being lithographed, the lettering and lining being made heavy accordingly, and, after all were completed, each sheet was reduced from a scale of 100 feet to the inch to one of 500 feet to an inch, by photography, and the whole work printed on one sheet. This work was done by the Boston Heliotype Printing Co., and is the result of no small patience and skill on their part. As the sheets differed slightly in size, it was necessary to do some "fudging" along the edges to make the two sheets meet, which accounts for some of the rough lines on the lithograph.

The work was begun in November, 1894, as I have before stated, and the field work was completed early in September, 1895, the plans being all rendered in October of the same year, or some four months previous to the agreed time. It was our purpose at

first to do but little work from June to October, as the leaves were sure to give much trouble, as they certainly did, but as we performed the most troublesome work first, we concluded not to stop, but to keep all our men on this work to its end, and, while we might have saved considerable trouble from leaves by waiting, we should probably have lost the difference by the men getting out of practice.

We consider ourselves as having been most fortunate in the men which we gathered about us for the purpose of this survey. They evinced great interest and skill in the work and bore the actual hardships of a severe winter without grumbling. With one or two exceptions, the "roughing it" which they underwent did great things for their health and left them much improved physically.

The plans resulting from our labors represent efforts to turn out plans of the greatest accuracy and represent an expenditure of time and money which we should not have felt warranted in spending had we been in the direct employ of the State, which no doubt strengthens our belief that under ordinary circumstances any municipality or commission gets better results under specifications and an ironclad contract than when doing construction or other work themselves.

TOPOGRAPHICAL SURVEYS—METHODS USED ON THE VANDERBILT ESTATE AT BILTMORE, N.C.

By John L. Howard, Member of the Boston Society of Civil Engineers.

[Read before the Society, October 21, 1896.*]

Mr. George W. Vanderbilt's North Carolina property, or the Biltmore estate, as it is called, is a part of the table land lying between the Blue Ridge and the Great Smoky Mountains, in the western part of the State, about 40 miles from the Tennessee line. The greater part of the country is at an average elevation of 2,000 feet above sea level, surrounded by numerous mountain peaks rising to 5,000 and 6,000 feet above the sea and only about 20 miles from the highest peak east of the Rocky Mountains—Mt. Mitchell —6,707 feet high.

The railroad station at the entrance of the estate is called Biltmore, and is two miles east of Asheville (a city that is quite well known throughout the North as a winter resort for those having throat and lung troubles).

It is on the main line of the Southern Railway at a junction of its southern branch to Atlanta and Columbia; and is about 24 hours' ride from New York.

Messrs. Olmsted, Olmsted, & Eliot, of Brookline, Mass., were in charge of the landscape work, and the late Richard M. Hunt, of New York, was the architect.

One of the first things asked for was a topographical map of the estate, and the problem which presented itself for solution at Biltmore, and the reasons which caused the adoption of the methods used there may be briefly stated, as follows:

Given 9,000 acres of land of a rather broken character, about equally divided between wood land and open fields, much of the woodland being very thick with a young growth of scrub oak, pine, etc., and many of the hill slopes running from 5 per cent. to 35 per cent., to determine upon a method which would show contours of 5 foot intervals with sufficient accuracy for the laying out of roads, and that could be done quickly; so as to have it completed in as short a time as possible. The method should be as simple as possible, and one that would not require much calculation, as skilled assistants were hard to get in that part of the

*Manuscript received April 26, 1897.—Secretary, Ass'n of Eng. Socs.

country, all of the help except the assistant in charge of the party, being farmers' boys who had attended school for perhaps six or eight weeks, twice a year for three or four years, who could read and write and do problems in simple arithmetic, but that was the extent of their knowledge.

As is usual in most cases when work is started upon a new undertaking, maps of certain portions of the territory were wanted at once, in order that the work might not be delayed, so some 200 acres were surveyed by the usual method of cross sections—stakes being put in by a transit in 100 feet squares and levels taken with an instrument on lines 25 feet apart through these squares. But it was soon seen that this method was both too costly and too slow, as well as needlessly exact, so after about six months' trial it was abandoned, and the following method, suggested by the Chief Engineer, Mr. W. A. Thompson, was adopted:

A base line was first run as nearly as could be estimated, through the center of the property in its longest direction, and at intervals of 500 feet points were established on locust stakes 4-in. square and about $2\frac{1}{2}$ feet long, driven into the ground to within 4 inches of the top of the stake. The distances were very carefully measured with a 100-feet Chesterman steel tape, at least once in each direction, by two different parties. These stakes were numbered from 0 at the North end, increasing toward the South. From these 500 foot points, lines were run with a transit at right angles to the base line, and on either side of it, and stakes were put in 100 feet apart on these lines. These stakes were lettered from A to Z with the omission of the letter J, so that one alphabet covered 2,500 feet. The stakes west of the base line were marked plus, and those east of the base line were marked minus. Then the height of the ground at each of these 100 feet stakes was taken with the usual level and rod. This completed all the field work necessary before coming to the actual determination of the contours on the ground. The map of the whole estate, it was determined, was to be plotted upon a scale of 200 feet to an inch, from which lithographs could be made and reduced to any scale desired. This made the size of the original map 8 feet x 15 feet. A sheet of cross-section paper divided into tenths was then taken, wide enough to cover a width of 1,000 feet on a scale of 200 feet to the inch, and long enough to reach from the base line to the extreme limit of the property. On this sheet was plotted the elevation of the ground at the stakes 100 feet apart on parallel lines separated from each other by a distance of 500 feet.

The topographical party consisted of the head of the party,

with a hand-level and the sheet of cross-section paper described above, and three boys with one 12-foot self-reading rod and two flags, made of a pole about an inch in diameter and 7.0 long, with a piece of red flannel about 2.0 square tacked on one end, and the other end shod with a steel point to stick into the ground.

The duties of the party were as follows: On arriving at a stake on one of the 500 feet lines one boy was sent ahead with one of the flags to the next 500 feet line, and told to stand over a stake corresponding with the one at which the rest of the party were waiting. For instance, if the rest of the party were at stake A 80, he was told to go to stake A 85 or A 75, according to whether they were working North or South on the base line. When he arrived at that point he would wave the flag, if in sight, and, if not, as was usually the case, he would shout, and the direction would be taken for the sound, as nearly as possible, with such assistance as could be obtained by "squaring off" a right angle from the transit line at the starting point. Then, with the rod on the ground at a stake the elevation of which was plotted on the sheet of cross-section paper, the head of the party would go up or down the slope until he read on the rod held by one of the boys enough to make the elevation of the hand level an even 5 or 10 feet. Then the other boy would pace the distance from the rod to the hand level, and the distance would be plotted on the sheet of cross-section paper, then the rod would be sent ahead until another 5 or 10 foot contour was reached, when the distance was paced, then plotted, and the operation repeated as before until the stake on the next 500 foot line was reached, when the distance as paced was checked by the location of the stake, which had been put in with a transit and tape, and the elevation of the ground as carried over the distance of 500 feet by the hand level was checked by the elevation, plotted on the cross-section paper as determined with the level and leveling rod. It was found that the elevation could be carried by the hand level a distance of 500 feet, with an error of less than 0.5 of a foot. Sometimes it would check exactly, and sometimes the difference would be a little more or a little less, but if it was more than one foot, it was certain an error had been made somewhere in reading the rod, and by going over the line again the error could always be detected.

The distance, also, would usually check out within 9 feet, and on a scale of 200 feet to the inch, that was not a serious error. It was surprising how closely those farmers' boys, after a little practice, would come in pacing 500 feet over some of the roughest kind of country, and up and down such steep slopes. One of the boys

at Biltmore was especially good in that respect, almost invariably checking out, either exactly or not more than 3 feet out of the way. I was a little sceptical at first about this performance, for it seemed almost impossible that such good pacing could be done for that distance and over such rough and uneven country, but, after watching very closely for several days to see if the boy did not lengthen or shorten his stride as soon as he came in sight of the stake, in order to make the distance come just right, I came to the conclusion that it was perfectly feasible, and that there was no juggling attempted in the last 100 feet or so. But the average error in distance was about 9 feet. The contours were sketched in in pencil on the cross-section paper, and where inked in with *water-proof ink* the next morning before starting out to work for that day, as if left in pencil, the sketch would be so blurred by the next day's handling that it would be impossible to tell one contour from another. I say water-proof ink was used, because at first water colors were used, burnt sienna for the contours, prussian blue for the brooks, etc., but after working through wet bushes and having the water drop off onto the sketch and the seeing the colors all run together regardless of contour lines, the practice was abandoned, and the water-proof inks were found to answer the purpose very well.

The amount of work done in this way per day depended of course, upon the character of the country worked over and the number of hours spent in actual field work. It was found that eight hours of actual field work, by this method, would cover about 40 acres per day. There were certain portions of the work that were so far away from head-quarters that not more than five hours of actual field work were accomplished, the rest of the time being spent in getting to and from work. And that seems to me one of the most important points in this class of work. Have your men live near the place where they are working, so that they can begin work in the field by 8 A.M., and the work will be sure to go on with good results both in cheapness and rapidity.

The cost of the work figured out to about $1.00 per acre, distributed as follows: 32,000 feet of base line for the whole estate, 500 feet of which could be run in a day with a force of

1 assistant as head of party@	$4.00
2 chainmen@$1.00	2.00
1 transitman@	2.00
2 axemen@$1.00	2.00
Total cost per day	$10.00

and for 32,000 feet that would amount to $640.00; the total area referred to base line being 9,000 acres that would make the cost per acre for base line work 7 cents.

Of the parallel transit lines 500 feet apart, with stakes at each 100 feet, 3,000 feet could be run in a day with a force of

1 assistant, per day	$4.00
1 transitman, per day	2.00
3 ax and chainmen, per day	3.00
Total cost per day	$9.00

3,000 feet in one line is equal to 1,500 feet on two lines, and as the lines were 500 feet apart that made an area of 17.25 acres, which was done at a cost of $9.00, or 52 cents per acre.

Leveling with an instrument over stakes 100 feet apart on the lines at right angles to the base line, 5,000 feet could be done in a day with a force of

1 transitman, per day	$2.00
1 rodman, per day	1.00
1 axeman, per day	1.00
Total cost	$4.00

This was equal to 2,500 feet on two lines 500 feet apart, or an area of 28.75 acres, making the cost per acre 14 cents.

With the hand level 40 acres were covered in one day with a force of

1 assistant, per day	$4.00
1 man to pace distances, per day	2.00
2 flagmen, per day	2.00
Total cost, per day	$8.00

which is equal to a cost of 20 cents per acre.

In plotting the work it was found that one man could plot and ink in, in one day, as much as three parties in the field could do in a day, or about 100 acres, and at $4.00 a day that would make the cost for draughting about 4 cents per acre.

A summary of the cost would be as follows:

Base line, per acre	.07
Transit lines, per acre	.52
Levels, per acre	.14
Hand levels, per acre	.20
Draughting, per acre	.04
Total, per acre	.97

The advantages claimed for this method are:

First. Simplicity; no calculations are needed as in stadia

surveys to reduce stadia distances to horizontal distances, or to reduce vertical angles to difference of feet in elevation, and then subtracting to get the correct elevation.

Second. Accuracy; the advantage of having the contours drawn in the field by the man who is making the survey rather than by an office assistant, who has never been over the ground himself, sketching it from the notes.

Third. Rapidity; 40 acres a day for a party of four.

Fourth. Cheapness; $1.00 an acre.

Fifth. As little cutting of trees as possible, the only cutting necessary being on the base line and the transit lines, as it was found none was needed on the hand level work.

Of course it takes some time to familiarize a party with this kind of work, and it may be two or three weeks before 40 acres will be the usual amount of ground covered in a day, but after the party is accustomed to the method, I have no doubt that they would often do more than that. As an instance, I may say that when this method was first used, about 75 acres was the average total of a week's work, but on the last survey made by this method 1,000 acres were done in four weeks by a party of four. That is, the hand leveling was done in four weeks; the staking out was in addition to that.

The maps made by this method answered their purpose admirably. The landscape architects found no fault on the ground of inaccuracy with the maps furnished them, and the roads laid out by them from those maps were found to be perfectly feasible and within the limit of 6 per cent. which had been set upon all grades. So that the method was considered a success by those who adopted it, and they have no hesitation in recommending its use to others under similar conditions.

EUROPEAN ROADS.

By Wm. R. Hoag, Member of the Engineers' Club of Minneapolis.

[Read before the Club at its Good Roads' Session, February 23, 1897.*]

The foot path made by the savage through the jungle or across the prairie—the hardended way over which the huge blocks of stone were transported by ancient builders for constructing their walls, temples and forts—the military road of Europe during mediæval times—the post roads and common highways and boulevards of modern times, and the railroads of to-day; each in its peculiar way has been a solution of the transportation problem. And each was perhaps suited to the age and people producing it. Each solution has been not only a positive indication of the needs of the people and of their state of civilization, but it has truly reflected the genius and capacity of the people and their ability to appreciate and supply such recognized needs.

Until the advent of some form of the wheeled vehicle there was no need of a road surface other than that furnished by the natural soil, and little or no grading was required as pack-trains could follow any trails on which man could travel with safety.

Wheeled vehicles may be said to have been used as early as the tenth century before the Christian era. At this time the Egyptians used rollers in transporting heavy stones from the quarry to the seat of construction. The substitution of two wheels for the roller, thus bringing increased load on a portion only of the track, which probably took place soon after among the Romans on their war chariots, marked the real beginning of the need of a special preparation of a road surface together with a suitable foundation. The Greeks are credited, even earlier than this, with having some worthy examples of highways, but these seem to have exerted little influence on subsequent road building.

The Romans were the first to realize the necessity of suitable roadways over which to transport their vast armies and munitions of war. We have good evidence that they had constructed such roads as early as the third century, B. C., for at about this time one of Hannibal's armies made a march of 600 miles at the rate of forty miles per day. This was possible only over a well-constructed roadway. The Roman highways were characterized by massive-

*Manuscript received April 9, 1897.—Secretary, Ass'n of Eng. Socs.

ness—which may have come from the national habit as well as from lack of knowledge of the strength of the material employed. A further fact which may have contributed to this style of construction consists in their using slave labor, thus freeing them from the usual economic considerations. The Roman appreciated the needs of the firm foundation and the impervious wearing surface, and usually secured these essential features though at great cost. He reasoned that the solid foundation could be secured only by building it of broad stones as thick as the desired foundation. He thus lost sight entirely of that peculiar cementing element in broken stone when compacted with chippings and stone dust, which is the secret bond of our macadam roads.

After the downfall of the Roman empire, the spirit of road building passed away. During the midiæval period, when Europe was dissolved into its local elements; when each petty ruler held his small estate more securely from his quarrelsome neighbor through the agency of impassable roads, no transcontinental lines were needed, and those left by the Romans in southern Europe lapsed into ill condition or were purposely destroyed.

Charlemange is said to have partially revived road building in the eighth century in order to consolidate his scattered provinces, but nothing permanent resulted from it. The period of modern scientific road construction has been developed so recently that to-day we still see, in parts of Europe, marks of the costly highways of earlier ages. Through England one occasionally finds broad roads sometimes a hundred feet or more in width, which were constructed by the Romans, and were evidently better suited and doubtless more used for purposes of war than of peace.

The movement for modern, better roads can be said to have begun about a century and a quarter ago during the reign and by the agency of that marvelous despot, Napoleon I. of France. His Italian campaigns acquainted him fully with the importance of good highways. The patches of old Roman roads still remaining furnished him ample proof of their value in time of war. Of all the legacies which Napoleon left to France and the world, none are greater or more far-reaching in their benefits to mankind than the splendid system of roads which resulted from the impulse given by him. Great credit is due to the French engineer, Tresaguet, who about 1764 began the systematic direction of the highway building in France. He imitated largely the Roman style of massive construction, using the heavy blocks beneath with a thin covering of broken stone and further greatly reduced the expense by building much narrower roadways. His name deserves to stand

beside those of Telford and Macadam, who were truly his disciples and took up the work about half a century later.

ENGLAND A PIONEER.

England, given less to consideration of war than the continental countries of Europe, attempted early in the sixteenth century some feeble legislation for the improvement of her highways for commercial reasons. Macauley, a century and a half later, writing of the common roads of the kingdom, notes that no substantial advance had then been made in the work of improving her roads.

There are striking features of similarity between the progress of road-building in England and in our own country, with a difference only of about a century in time. History is here truly repeating itself. Great Britain undertook the work of improving her highways mainly with reference to commerce; her agricultural and manufacturing industries as well as good road material greatly stimulated this movement. Our conditions in this country are quite similar, our industries, as well as our social conditions, being so much like those of Great Britain. And yet, with this tardiness in highway improvements, may we not inquire with some profit why we are thus lagging one hundred years behind our mother country when in all else which counts for civilization we justly claim a place beside her and all the other and older nations of the world. Must we go over the same tiresome way that England has traveled, to reach the good road? England, a hundred years ago, had her system of "working out the highway tax" strikingly similar to what we are now reluctantly parting with long after its utter inadequacy has been demonstrated. She had also, besides her poor roads, a system of "parish management" by persons chosen each year to become roadbuilders. They had no special knowledge or fitness for their work, and the dirt roads of England seventy-five years ago under their management were much like our roads of to-day. The points of resemblance between the system which produced only bad roads in England then, and that which is doing the same for us to-day, is too striking to require comment. Continuing with this thought of resemblance, Mr. Potter remarks: "In 1819, while the question of improved roads was occupying the attention of Parliament in about the same manner that it is attracting the attention of legislative bodies throughout the United States to-day, Mr. Telford appeared before the parliamentary committee on roads and highways and gave graphic testimony of the real condition of the British roads of that period. The interest then awakened grew from year to year till 1835, when Parliament passed the

general highway act, and from that date began the systematic and intelligent management to which the superior qualities of the English road is now principally due." Quickly following the example set by England, the other countries of Europe were little behind in constructing a system of highways little if any inferior to that of England. By a system of administration very similar and plans of construction and maintenance frequently almost identical, except to meet slightly different local conditions of material, national customs and social laws, nearly all the countries of Europe to-day possess systems of highways which are at once their pride and their wealth and the envy of visiting Americans.

HIGHWAYS CONNECT NATIONS.

In Ireland these highways add much to the picturesqueness of the Killarney district. In France you may ride over the same matchless highways from Paris to Orleans and on to Nevers and across the Jura mountains into Switzerland. You may journey through this delightfully refreshing country and on through Germany and follow the Rhine to the North Sea, and everywhere you will find good roads. You will travel with equal pleasure the roads of Scotland, Italy, Austria, Belgium or Scandinavia, and you will everywhere find that the public hand has been intelligently directed to building and maintaining common highways. "Each of these countries has established, within its civil government, a department having control of the more important highways and in most cases a supervisory management of the parish and branch roads. There is a practical unanimity among the great countries of Europe in this policy of government direction." Its foundation lies in the recognition of the principle that the highway, like the public postoffice or courthouse, is public property, dedicated by law to the use of the public; and further, that the waste of time and property which had been going on for centuries in Europe by the use of mud roads could be checked only by the construction of high-class roads under an intelligent central authority. This was the doctrine of the French engineer, Tregasuet, and later of Telford and Macadam. One who has made an exhaustive examination of the plans of twenty-three separate states, reports that in each case the quality and condition of the public roads were improved or injured in the same measure that the general government bestowed or withheld its official supervision.

"What is the commercial value of these highways? Why does the nimble-witted Frenchman spend $18,000,000 per year to maintain good roads? His quick answer is, 'It pays.' He knows

that a horse can take to market twice as much on a Macadam road as on a dry dirt road, and four times as much as on the average dirt road in average condition and eight to ten times as much as when the dirt road is turned to mud by the fall and spring rains. He also realizes fully its effect in shortening the distance to market; its effect on land values; its saving to wagons, horses, etc.; he knows that it quickens social communications and adds wealth to the individual and the state. The American farmer will doubt this, but the Frenchman knows it for he has tried both ways."

A recent writer has said: "It is impossible to read the history of the reform in European highway management and the heroic work of the men to whom the credit of that reform is due, without noting the fact that the friends of good roads, who fought their battles for better laws in the British Parliament, were only pioneers in the same work in which many intelligent Americans are engaged to-day. Theirs was a task which took years to accomplish. They were met by the same arguments which impede the movement in this country sixty years later. Their motives were doubted, their methods criticised, and their final success was attained only by the most persevering steps. If our common boast that we are a progressive, wide-awake and ingenious nation is well founded, what can be urged to excuse us for adhering to the intiquated and inefficient methods of keeping our common roads, when we have before us the great economy and splendid results produced by the adoption of more intelligent methods in other countries?

QUESTION OF EXPENSE.

But the question is frequently asked: "Can the people of this country afford to build and maintain high-class roads? Is not ours a new country, and can we expect to rival the countries of Europe in the construction of costly internal improvements?" The answer to these questions is forever ready. Ours is not a new country. We are rich and populous, and we claim to be intelligent and enterprising. It is an encouraging circumstance that the importance of this question is gaining recognition in the councils of our government and in many of our States. In a recent report of the committee of agriculture, the condition and urgent needs of American roads is stated in language clearly indicating the importance this subject holds in the consideration of the writer. The commissioner says: "The common roads of the country are the veins and arteries through which the agricultural productions and the agricultural supplies, which are the lifeblood of the nation, pass to

greater ducts of travel and transportation—the railroads of the country.

"While our railway system has become the most perfect in the world, the common roads of the United States have been neglected and they are inferior to those of any other civilized country in the world. They are deficient in every necessary qualification that is an attribute of a good road: in direction, in slope, in shape and service, and, most of all, in want of repairs. These deficiencies have resulted not only from an ignorance of the true principles of road making, but also from the varied systems of road building in force in the several States in the Union, due to defective legislation. The principle upon which the several States have based much of their road legislation is known as the "road tax" system of personal service and commutation, which is unsound as a principle, unjust in its operations, wasteful in its practices and unsatisfactory in its results. It is a relic of feudalism borrowed from the 'statute labor' of England, and its evil results are to-day apparent in the neglected and ill-conditioned common roads of the country.

"It is a question of vast importance to the welfare of this nation that these arteries of agricultural and commercial life should receive the attention that their importance deserves, and that an effort should be made to remedy the defects now existing and establish a system that could be made uniform and efficient in all the States of the Union."

What, then, is the remedy? Granting that we are in the mud, and deep, too, what is to be done? Will philosophizing as to how we got in help us out? It may be comforting to shift upon some other party the responsibility of our being in. We might say that the railroads are largely to blame for becoming so numerous and well organized and operated that the business that would have demanded the betterment of our highways has been taken by them.

RAILROADS HAVE THE LEAD.

The railroads "got the start" of the highways in this country and have outstripped them. In England the highways were well under way before the advent of the railroads. This may be comforting to contemplate, but still it leaves us stuck in the same unpleasant place in the road. The comforting thought that we have not had a fair race with the railroad will largely vanish if we will ask ourselves a few simple questions:

First—Is there any particular study made before a railroad is finally located?

Second—Is each few miles of the railroad under the entire charge of a different man?

Third—Does this man know anything in particular about the maintenance of way?

Fourth—Is this small section of road given into the charge of a new man each year, who will doubtless undo any good his predecessors may have done?

Fifth—Is one part of the road constructed or maintained with any reference whatever to any other part?

In a word, do we apply to the construction and maintenance of our highways any of the well recognized business and engineering methods which we know to obtain with the railroad and which have placed them second to none in the world? Now, to get out of the hole, one must fully realize that he is surely in. This is the mental process which must precede his putting forth the necessary extra effort to extricate himself. When the driver feels his wheels sinking and his load stop, he at once climbs down and walks around his wagon to make sure he is in and how badly, in order to determine about how much whip he must use to free his load.

Now, I seriously question if, as a people, we realize that our load has come to a halt and is badly in the mud. I believe we are still sitting complacently on top of the load, with now and then a lash at the horses, persuading ourselves that we are still moving, though, perhaps, slowly. There is little hope of reaching better roads here till we fully appreciate that we are now but wasting time and making no progress.

This country stands to-day in greater need of road missionaries than of road engineers. We need both, but we want one hundred missionaries to one engineer. At present, the ratio is about reversed. When a majority of the land owners know that good roads pay, we shall have good roads, and that soon. How this educational work can best be carried on is a question upon which some differ. Massachusetts, Vermont, New York, New Jersey, California and other States (at least ten years in advance of Minnesota in this matter) are believed to have found a solution. They have, uniformly, created a State Commission, to take the whole matter under advisement and, after two years' work and study of the question in all its legal, economic, engineering and local bearings, these commissions have reported back to the Legislature with recommendations for suitable legislation.

DRAINAGE OF COUNTRY ROADS.*

[Paper read by Mr. E. A. Whitman at the Good Roads' Session of the Engineers' Club of Minneapolis, held February 23, 1897.†]

One of the first and great causes of our poor highways is a lack of any system of drainage. Whatever may be the locality of a road, or whatever may be the material, it must be borne in mind that water is the greatest enemy to a road, and that some system for drainage must accordingly be adopted.

Roadway drainage is of two kinds—surface and sub-surface. The first provides for the speedy removal of all water which may in any way come in contact with the surface of the road; the second provides for the removal of that which comes in contact with the body of the road. The drainage of the road surface depends upon keeping the section higher in the center, with uniform slopes to both sides, without hollows or ruts in which water can lie, and upon the longitudinal fall. The slope necessary from the middle to the sides of the road will be determined by the nature of the covering, being less as the road surface is more smooth and less permeable. It should be steep enough to cause the speedy removal of the water without washing the surface.

There are two forms of this section—one with a convex curved surface, the other with two plain uniform slopes, one in each direction—but it is not a matter of importance which is adopted, so long as the section is kept highest in the middle.

The longitudinal fall of the road must be sufficient to protect the road from becoming flooded during rain storms and melting snow. This slope should be from 1 in 100 to 1 in 120 on broken stone or earth roads. To prevent the gutter from washing where the slope is steep, they must have some form of pavement, or the water must be removed at frequent intervals, in order to make the flow small. To obtain this last result, a pipe may be laid underground. As a general thing, surface water from our country roads can be easily disposed of; but we often find it in the gutters, where it keeps the road-bed saturated, and consequently causes great injury to the road. In the case of a heavy gradient, and only in such cases, water-breaks are used to collect the water at certain intervals and turn it into the gutters or side ditches.

*A "technical essay" prepared by Mr. Whitman in the regular work of "Highways" in the Civil Engineering Department of the University of Minnesota.

†Manuscript received April 9, 1897.—Secretary, Ass'n of Eng. Socs.

These water-breaks are broad and shallow, generally paved, and so arranged as to carry water from the middle to each side of the road. Although those points mentioned above may be well followed out in the construction of a road, we may still have a very wet road-bed, and this will have the most damaging effect upon the road covering. The only help, then, is a perfect system of sub-drainage, which is most essential to a good road and will prove to be economical in the end, even if the cost of securing it be large.

SUB-DRAINAGE.

The necessity of sub-drainage and the method to be adopted will depend upon the character of the soil and upon whether or not the road-bed has a natural drainage. As far as possible, all water should be cut off before it reaches the road-bed. To accomplish this, local conditions must be observed, the source of supply determined, and the nature of the underflow, if any exists, considered. Silicious, sandy loam and rock ordinarily do not retain water, and hence little difficulty is found in securing a dry road-bed. A ditch on each side of the road will generally be sufficient. Clayey soils and softer marls, being retentive of water, somewhat difficult to compact, and very unstable under the action of water and frost, require much more care.

The drainage of low and naturally damp soil may be accomplished by placing a longitudinal drain along each side of the road. If it so happens that the road lies along the side of a slope where there is a flow of sub-surface water from one side to the other, a single drain may be placed on the side of the road from which the water comes. Transverse drains, leading into the longitudinal side drains, may be adopted where the soil is very retentive of water. These transverse drains are placed not at right angles to the main drains, but in the form of an inverted V, with the point up hill, and with each branch descending to one of the side ditches. The apex is not less than 18 inches below the surface, and the fall of the branches not less than 1 in 5 feet. The distance apart of these drains will depend upon the wetness of the soil—15 feet for wet soil and 25 feet for drier and firmer soil.

On country roads, where an impervious surface is not used, a single longitudinal drain under the middle of the road will give good results, as it serves to move sub-surface water and that which percolates through the road surface.

DRAINS.

The drain to be used for the sub-soil of a roadway may be an open ditch or a porous covered drain. Open ditches, if any ditches

at all, are generally used on country roads, but these are poorly made, and even the best fall far short of relieving the road of its wet, soggy condition. Closed drains are more desirable and more commonly used where good sub-drainage is desired. Of these there are several different types, namely: blind, brush, stone, and tile drains. The blind drain consists of a ditch filled with rounded stones from 3 to 6 inches in diameter. The top of stone is covered over with finer stones, straw, or brush before filling in the earth above, to prevent the earth from washing down and choking the drain. The cheapest of all drains, when the material is at hand, is probably the brush drain. Two logs are put on the bottom of the trench, one on each side. Between these logs brush is laid transversely and thoroughly tramped into place. After a height of 3 or 4 inches is reached, poles are laid over the small brush, and they in turn are covered with earth. Charles W. Irish, C. E., Chief of Irrigation Inquiry, United States Department of Agriculture, says that such a drain, put in by himself to drain a spring under a railroad embankment of 18 feet fill, lasted for twenty years, and showed no signs of settling. The brush and timber seemed perfectly sound after the twenty years of burial.

Stone drains consist of rectangular or triangular boxes formed of flat stones or bricks along the bottom of a trench, and filled above as in the blind drain, so that water may enter readily.

Probably the tile drain is the most convenient and gives the best results. It is constructed similarly to the stone drains. The tiles are set end to end in the trench, and are held in place by small stones. A collar, which encircles the joint, allows a large opening, but prevents the entrance of material that would choke the drain.

In building drains of any of these types, there are four points that need special attention: First, outlet; second, grade; third, depth, and, fourth, protection of outlet. The object being to dispose of the water as quickly as possible, good, deep outlets must be secured. It will seldom happen that an outlet cannot be found, at comparatively short distances along the line of road, although it may sometimes prove economical to find one away from the direct course. The grade and the size of drain will be determined by the character of the soil and by the probable amount of water to be carried.

After an outlet has been found, a line of level should be run the entire length of the drain. The slope of a porous drain may vary from 1 in 40 to 1 in 100. In case a steeper slope is necessary, a foundation should be placed at the bottom of the trench, which

otherwise is liable to be washed by the current produced. The depth of the ditch should be from 2 to 3 feet, but ditches, like drains, should be laid below the frost-line.

At the outlet some method must be employed to prevent too great a washing of the soil if the outlet does not run directly into a stream. In the latter case the drain should terminate after passing through a stone wall, while in the former case the path of water may be rip-rapped for some distance. The end of the drain should have a good screen, to prevent vermin of any kind from entering to obstruct it in any way. In the case of tile drains, which are liable to be injured by frost, stone, drain, or salt glazed sewer pipe may be used at the exposed end.

CULVERTS—SIZE—CONTROLLING ELEMENTS.

Besides the several drains already mentioned, the culvert plays a very important part in the maintenance of highways. It is required to carry small streams under the roadway and to carry away the water collected by the side gutters and ditches upon the upper side to that side where the natural water-course lies.

A culvert must be large enough to allow the maximum amount of water to pass, and yet as small as possible to save cost of construction. The area of the water-way needed may be approximately determined by observing the following local conditions:—

First.—The rate of rainfall. The amount will vary in different localities, and differ from year to year. Except during heavy storms, the maximum rainfall, as shown by statistics, is about one-eighth inch per hour, equal to 3,620 cubic feet per acre. Only from 50 to 75 per cent. of this will reach the culvert during the hour.

Second.—The amount of water to be drained off. This will be determined by the character of the soil, its degree of saturation, the conditions of cultivation, and amount of vegetation.

Third.—The rapidity with which it reaches the water-course. The character of the surface, as to whether it is rough or smooth, steep or flat, covered with vegetation or barren, will determine this.

Fourth.—The character of the bed of the stream. The speed with which the water will reach the culvert will depend upon whether or not the water-course is unobstructed, whether it is of considerable inclination, etc.

Fifth.—The size and shape of area to be drained and the positions of branch streams. Although the area of water-way depends

upon the amount of territory to be drained, the shape of area and position of branch streams are of more importance, as they determine whether all the water will arrive at the culvert at the same time or whether the lower part will pass through before the upper waters reach the culvert.

Sixth.—The form of mouth and inclination of bed of culvert. The discharging capacity of a culvert may be increased with increase of inclination of bed, if the channel below allows the water to flow away freely. The uper end should be so arranged that the water may enter without decreasing its speed.

Seventh.—Whether it is permissible to back water up and discharge under a head. Most culverts should be constructed strongly enough to allow water to dam up about them. A culvert will discharge twice as much under a head of four feet as under a head of one foot. Several formulæ, derived from experience, have been produced for determining the area of water-ways, but these give only very rough approximations. Valuable data may be gathered by observing the existing openings on the same stream; by measuring, at time of high water, the cross-section of stream at some narrow place; and by determining the heights of high water, as shown by drift and by the testimony of old inhabitants. The question is merely whether the ordinary pipe or an arch culvert will answer the purpose.

MATERIAL.

The materials used in the construction of culverts are wood, stone, brick, vitrified sewer pipe, cement pipe, and iron pipe. Where the flow is small, either class of pipes or box culverts of stone or wood are used. Wood should be used as little as possible, if ever, as it is not durable. Any of the different kinds of pipes, varying in size from 12 to 24 inches in diameter, are very efficient, and can be procured comparatively cheap in most parts of the country. Where the flow is too great for two or three lines of 24-inch pipe, a stone or arch culvert had better be constructed.

Arch culverts are placed where the span is more than 5 feet, and if greater than 15 feet, a bridge is recommended.

IMPORTANT DETAILS OF CONSTRUCTION.

In laying pipe culverts, the following points must be observed:—

First.—The trench bottom must be constructed to fit the lower half of the body of the pipe, and, as a rule, deep enough to allow the top surface of the pipe to be at least 18 inches below the surface of the roadway.

Second.—The pipes should be uniformly and firmly supported, and the earth well tramped around them.

Third.—To prevent freezing, the pipes must have sufficient fall to drain themselves and enough outlet below to prevent back-water from reaching the pipes.

Fourth.—Joints should be water-tight to prevent water from getting through and undermining the pipes.

Fifth.—The ends should be placed in masonry or timber bulk-heads, although they are very often omitted. These walls should be deep enough to lie below the bed of the stream, and wide enough, unless winged walls are extended up the stream, to protect the embankment from washing.

In very small streams this wall will not be needed. Where it is necessary to save in construction, posts may be set in the ground and planks spiked to them. This is an imperfect substitute for brick or stone, but is much better than nothing.

These walls should always fit tightly around the end of the pipes to prevent water from entering at the sides. The water-way may be rip-rapped above and below the culvert, to prevent washing.

The simplest form of stone culvert consists of side walls of rubble-stone work laid dry or in mortar, depending upon the character of the stream, and a covering of large flagstones. This is a very economical structure where such stones are found. Attention must be given, as in the pipe culverts, to the end walls and paving of the water-way. The side walls should extend down to a good foundation. The thickness of the walls depends upon the pressure to come upon them, but is generally from one-half to three-fourths of the height.

The arch culverts are the most difficult and expensive to construct. They are made of stone, brick, or cement, and in various forms and sizes. On account of the cost they are seldom employed in the construction of country roads, but in their stead the small wooden bridge is employed, and is a comparatively cheap structure.

COST.

As regards the cost of building the different kinds of drains or culverts, it is difficult to give definite figures, as the prices of labor and material differ so much in different localities and at different times. Any form of either, however, can be built comparatively cheap, and, if the best form be employed for existing conditions, it will always prove to be a paying investment.

A NATIONAL BOILER INSPECTION LAW.

By E. D. Meier, Member of the Engineers' Club of St. Louis.

[Read before the Club, April 21, 1897.*]

I believe that before a body of intelligent engineers no explanation or apology is necessary for desiring a national boiler inspection law. Those whose profession fits them to understand, and whose daily experience teaches them to appreciate, the intimate connection of steam engineering, in its many branches, with the rapid development of every art and trade useful to the mass of mankind, will agree with me that the steam boiler, where the heat energy of fuel is stored in a form ready for instant translation into mechanical work, deserves more careful attention than it has heretofore received. In some, though not all of our large cities, special police regulations are made to govern, to some extent at least, the proper choice of materials, correct dimensions and good workmanship for steam boilers. And yet we all know that these regulations are crude and often faulty in the most important particulars. Probably the best of these laws is that enacted by the city of Philadelphia in 1864, and since then amended and approved at five subsequent sessions of the City Legislature. Besides being a good law, it has had the advantage of being interpreted by a chief inspector who stands in the front rank among those professional or technical public servants to whom our municipalities can never be quite thankful enough for the honest patience and skill with which they prevent or forstall the disasters which would surely overtake us if the average politicians could have their way. This Philadelphia law was, in the main, evolved by a committee drawn from the ranks of manufacturers, engineers and professional boiler inspectors. The city of Boston is without a boiler inspection department or boiler inspection law. But such a law has been recently enacted and is now in operation in the state of Massachusetts. New York City has an inspection department attached to its police force. The inspections are entirely perfunctory, and follow, in a crude way, the provisions of the U. S. Marine Inspection Law. The city of St. Louis has a fairly good ordinance, which has generally been conscientiously administered by good, practical, steam engineers. It also follows the lines of the U. S. Marine Inspection Law. The same is true of Allegheny county,

*Manuscript received April 27, 1897.—Secretary, Ass'n of Eng. Socs.

which includes the city of Pittsburgh and the adjacent manufacturing towns. Attempts have been made in the State Legislatures of Pennsylvania, Missouri, and Minnesota to pass a State law on the subject, but they have failed on account of the opposition of the manufacturers or users of agricultural machinery or of small oil and gas well boilers.

When we realize the immense number of steam plants, and the cupidity, misdirected by ignorance, which characterizes the installation and maintenance of so many of them, we may well wonder that disasters are not more frequent. There are three factors which have acted as safe-guards in the absence of laws on the subject. One is the intelligence and adaptability of the average steam engineer or engine runner. The other has been the intelligent self-interest of boiler inspection and insurance companies, first among them the Hartford Steam Boiler Inspection Company, which has gradually succeeded in establishing some sound, unwritten laws on the subject of boiler building and boiler management, and has spread much useful information by means of pamphlets and essays in trade papers. The third has been an honest pride in turning out safe work from their shops which has actuated most boiler manufacturers of the country, and which even ruinous competition in price has not been entirely able to obliterate. In this line also the American Boiler Manufacturers' Association has done much good work in recommending good and condemning bad materials and workmanship.

But with all these working in favor of good practice, it does seem that, for a nation, which, if not now, is sure to become the greatest manufacturing nation of the world, we have done ill to so neglect the regulation and safety of our prime motor. The only national legislation on the subject is that contained in the laws governing the Steamboat Inspection Service, and, with a few general provisions as to materials, these laws leave everything to the boiler inspectors, who "shall satisfy themselves that the boilers are well made of good and suitable material, and may be safely employed without peril to life."

England, France, Germany and Belgium all have an elaborate and carefully considered body of laws on the subject. There is much in these laws which we may judiciously follow and much which we should as judiciously reject.

It does seem as though a matter of such vital and far-reaching importance should be settled by the best talent and experience obtainable in the country, and that laws governing the construction and use of steam boilers should have a national scope. Whatever

may be our theories and our practical judgment in regard to the question of protection or free trade, when applied to foreign countries, we are (with the exception of a small coterie of local policians) all agreed as to the advisability of a perfectly free and untrammeled trade among the various States of the Union. Our magnificent system of railroads has made it possible for American manufacturers to compete for machinery of all kinds all over the country; it is but just that they and their customers should be free to sell and buy without any restriction except such as an enlightened care for the safety of life and property must dictate. The doctrine of State rights should not be invoked to prevent salutary legislation in regard to such matters.

I will not enter into the legal or constitutional difficulties in the framing of a law which shall accomplish this end. Once the desirability and necessity of such a law is understood, there are constitutional lawyers enough in Congress to frame its provisions in such a way that it shall not do violence to any article of the Constitution. There is at present a bill pending in the Senate to "establish the Department of Commerce and Industries." It is intended to transfer to this department those functions of the Treasury Department which do not rightfully belong to it. Many of these were added to the duties of the Treasury Department at a time when they were small, and no one anticipated their rapid growth. They have now become of vast importance, and need the fostering care of a department in which they are not merely recognized, but whose principal business, in fact whose reason for existence they constitute. To this department would naturally be confided all regulations bearing on the safety of the machinery of commerce and of manufactures, and hence Section 4 provides that the Life Saving Service, the Light House Board, the Bureau of Navigation, the Bureau of Steamboat Inspection, etc., shall belong to this department. This Bureau of Steamboat Inspection Service has charge of the boiler inspection and regulation on all navigable waters of the United States. Our great manufacturing cities, naturally situated on the principal waterways, as soon as they found the need of regulation of steam boilers, turned to the rules of this Bureau for guidance. It was unavoidable that many provisions which modern science and modern practice has rendered obsolete, or shown to be erroneous, should still be found in the rules of the Bureau and be transferred to the ordinances of these cities. When we examine the meagre provisions of the law establishing and governing this Bureau, we are forced to admit that it has accomplished much, and to congratulate it upon the few

mistakes it has made. If it has not kept pace with the progress of manufacture and of steam engineering in this country, it is because its opportunities have been limited by causes which it had no power to control. In regard to the matters confided to its charge it has a large experience and a valuable body of statistics. This Bureau should have been enlarged, and its power and possibilities much extended. It has to deal with many matters besides boilers. Out of thirteen subjects as given in the general rules and regulations of January, 1896, only two refer to boilers and boiler-plate. For the whole United States there are only ten districts, each in charge of a Supervising Inspector, who numbers among his assistants from one to ten boiler inspectors. The board of ten Supervising Inspectors meets but once a year for a few weeks at Washington, D. C., and the time is too short to undertake a general review and improvement of the rules applying to boilers. And yet these rules are in many ways in advance of the regulations of foreign countries. Thus, for instance, neither the German nor the Belgian law contains any provision in regard to the quality of the steel or iron entering into the construction of a boiler, but this United States Board of Supervising Inspectors has gone into the matter at some detail, and gives very intelligent rules in regard to the qualities desirable or necessary and the tests for determining them. And these rules have no warrant in the letter of the law establishing this bureau, but are based entirely on its spirit, and promulgated in the confident hope that they will not be called in question. And such is the respect in which this board is held by manufacturers and builders all over the United States, that these rules are complied with without question. This general acquiescence is based on a knowledge of the usefulness as well as of the conservatism of this board.

Some years ago I had occasion to look up the statistics of boiler explosions, and will here quote some of them. The number of boiler explosions in the United States varies now between 200 and 300 per annum. During the fourteen years ending in 1892 there were in the United States 2,685 explosions, resulting in 3,684 deaths and 5,185 injuries. This means that every explosion kills 1.37 persons and injures 1.93, making a total of 3.3 persons. Taking the average value of a life as established by our courts as $5,000, and averaging the injuries the same, this shows that every explosion causes a loss of at least $16,000 to the community, or that boiler explosions every year cause a loss of between three and five million dollars. As might be expected, most of these occur in the rural districts, where there is no inspection, and where

the moral influence of the licensing of engineers and inspection of boilers on the navigable waters and in the large cities is but little felt. Take the year 1892, as an example. There were 269 explosions, with a record of 298 killed and 442 injured. Out of these only 11 explosions, or a trifle over 4 per cent., occurred on steamships or steamboats; 140, or somewhat over 52 per cent., were in saw mills, mines, and other industrial establishments remote from large cities. This leaves only 44 per cent. for the very much larger number of boilers found in the large cities, and including that vast number of locomotives constantly in use on the railways of the country. This proves that intelligent inspection and supervision can and will reduce losses from this source to a minimum. Whoever reads the details of the enormous boiler explosion in the colliery at Shamokin, Pa., cannot fail to see that a State inspection law, honestly carried out, would have prevented it entirely.

The records of the United States Steamboat Inspection Service bear out this view in a marked degree. The following table gives the data for three decades:—

Decade.	Lives Lost p. a.	Total No. of Steamers.	Steamers p. life lost p. a.	No. of Travelers p. life lost p. a.
Ending 1868	721	1,687	2.34	138,700
" 1878	365	3,645	10.00	821,600
" 1888	213	5,344	25.00	2,347,400

We see, therefore, that in the second decade traveling had become six times as safe, and in the third decade seventeen times as safe as it was during the first.

In January, 1892, Senator Frye introduced a bill to improve this steamboat inspection service so far as it referred to boilers, mainly on the basis of recommendations made by United States delegates to the International Marine Conference. This was defeated chiefly by the active opposition of American boiler manufacturers and by the friends of the present steamboat inspection service, and this was for sound reasons. Many of the new rules proposed were based on European practice, and did not recognize the unquestioned superiority of American materials, nor improved methods of manufacture adopted by the best American shops. The mistake made in this instance was that the move was undertaken without gaining or asking the co-operation of those most vitally interested. At the same time the methods of the opposition showed plainly that such co-operation can be obtained and an American law framed, based on American conditions which will command the respect and cheerful obedience of those most

directly interested. On such lines the matter may be and should be again taken up.

The interest in the establishment of a department of commerce and industries with a cabinet officer at its head is so general, so great and growing, that we may reasonably expect the Senate bill to pass during this session. As soon as that is accomplished a remodeling and enlargement of the various bureaus assigned to this department will be in order. A bill similar to the Frye bill of 1892, drawn after full consultation with the head of the present Steamboat Inspection Service and with such organizations as the American Boiler Manufacturers' Association, the Association of Marine Boiler Manufacturers, etc., can readily be passed. This bureau should then have, at headquarters in Washington, a permanent committee of scientific and practical engineers charged with the duty of investigating and following the advances in steam engineering, and especially in boiler materials and boiler manufacture, so as to present each year a well-digested review of this progress, and on this basis to recommend such additions to or amendments of existing rules as will hold marine boiler work on a level with the best practice of the country.

A bureau which has done such good and faithful work under entirely inadequate provisions for its maintenance deserves the encouragement which such a law would give, and under the same it would soon brush away many unfit survivals of earlier practice. The step made in 1896, in Rule 1, as to requirements for boiler-plate, is a decided step in advance. Not only is the new test section a great improvement on the former one, and substantially in agreement with the testing practice of leading engineers of the country, but the introduction into the rules of chemical requirements in regard to minimum percentages of phosphorus and sulphur is of inestimable value.

I had occasion to point out to the Board of Supervising Inspectors certain discrepancies in their rules and actual departures from the section of the law under which alone these rules have any legal force. The two sections of the present law are as follows, both being found under Title 52, Revised Statutes of the United States:—

"Section 4433. The working steam-pressure allowable on boilers constructed of plates inspected as required by this title, when single-riveted, shall not produce a strain to exceed one-sixth of the tensile strength of the iron or steel plates of which such boilers are constructed; but where the longitudinal laps of the

cylindrical parts of such boilers are double-riveted, and the rivet-holes for such boilers have been fairly drilled instead of punched, an addition of 20 per centum to the working pressure provided for single-riveting may be allowed; *Provided*, That all other parts of such boilers shall correspond in strength to the additional allowances so made, and no split-caulking shall in any case be permitted."

"Section 4462. The Secretary of the Treasury shall make such regulations as may be necessary to secure the proper execution of this title."

Section 4433 distinctly requires a factor of safety of 6 on single-riveted boilers and one of 5 on boilers with longitudinal laps double-riveted with drilled holes. There is no warrant for construing this section otherwise than to apply to the net section of metal anywhere in the boiler. Yet the practice has grown up, and the rules permit it, that this stress is figured on the full metal in those parts of the shell where there are no rivet-holes, and not as it should be on the net metal left standing between the rivet-holes.

Now bear in mind that we cannot expect rivets to stand more than 40,000 pounds shear, as against 60,000 pounds tension in the net metal, and that it is practically impossible to make a double-riveted seam in which the net metal shall have a greater value than 70, or at most 72 per cent of the full metal of the sheet. Practically speaking, therefore, the rules and practices of the inspection bureau have reduced this factor of safety in the net metal from the legal limit of 5 to only $3\frac{1}{2}$. When engineers draw specifications for land boilers they never allow a factor of safety of less than 5. The fact that marine boilers are run with safety with a factor of only $3\frac{1}{2}$ can be accounted for only by the frequent and careful inspections made by this steamboat service, and the promptness with which the inspectors reduce the pressure allowed on boilers as soon as the slightest corrosion becomes apparent to their practiced eye. And it is a well-known fact that steamboat boilers are thrown out after comparatively few years of service, and always blow up AFTER they have been placed in saw mills, etc., in the interior, where there is no inspection. The reason for this departure from the law in the established rules is probably to be found in the fact that on the Mississippi river and its tributaries the muddy water and scale makes a thickness of metal of more than 0.3 inches unsafe, and the larger

boilers of the lakes and eastern rivers and sounds are internally fired, so that deterioration of the structures results only from internal corrosion, which can be largely prevented by careful supervision.

I noted, however, some curious inconsistencies in the rules in relation to bumped heads and stay-bolts. The rule for the thickness of metal in bumped heads has been arbitrarily framed by introducing as the divisor six-tenths of the radius of curvature, instead of five-tenths, which is mathematically correct. In this way, instead of a factor of safety of 6, a factor of 7.2 is exacted. I have been unable to find any reason for a factor of safety in the solid plate, unpunctured by rivet-holes, somewhat over twice as great as that exacted in the riveted lap-joint.

In regard to stay-bolts, the rules take into consideration the tensile stress to which the stay-bolt is subjected. As most stay-bolts fail under test by shearing of the threads, and as this is again induced by the buckling of the plates, thus drawing the threads of stay-bolt and plate out of mesh, it is certainly incongruous that neither this shearing nor this buckling should be recognized in the rules, nor is the quality of the material in the stay-bolt given any consideration. Therefore, a manufacturer is at liberty to use an inferior metal in his stay-bolts, to make the plates stayed thinner than they should be, and yet pass inspection, provided only that the stress on the net section of his stay-bolt does not exceed 6,000 pounds, if made of iron, or 7,000 pounds, if made of steel. As threads on steel stay-bolts will not stand as much shear as those of good ductile iron, here is another incongruity. Such discrepancies and erroneous provisions can be successfully attacked before a committee composed of technical experts. But a large body of supervising inspectors, who have a multitude of duties, altogether apart from the questions of boiler construction, cannot be expected to do them justice in a short session, unless the details have been gone over by a responsible technical committee and the main facts submitted to the board for its judgment and final action.

Having freely criticised such faults as I have found, it is clear that I do not contend that this board of inspectors is an infallible resort. But its members have generally been men of long service in connection with marine machinery, and they have therefore, as a rule, a trained judgment which will enable them to weigh justly such recommendations as the technical committee may make. Manufacturers or purchasers of machinery would have to submit intended improvements to the criticism of the technical commit-

tee and the supervising inspector general would get the final advice of the board before embodying such changes into rules which have the force of law. Thus assisted and reinforced, this board would meet the higher and larger requirements which the constant improvement and expansion in steam engineering naturally imposes upon it, and while providing for constantly-increasing safety on all steam craft, it would not stand in the way of any real improvement.

Just how land boilers might be made subject to the same rules is a matter for the legislator. Experience has shown that the only governmental inspection bureau in the country, crude as many of its provisions necessarily are, has so commanded the respect of those communities where its beneficent effects became known, that they readily adopted its provisions in local ordinances. With the growth of national sentiment everywhere apparent, and with the growing and imperative demands of our vast internal commerce, some way will be found. As modern life becomes more complex, and as many citizens are compelled to use and be subject to the dangers which modern machinery carries with it, the necessity of national police regulations in regard to boilers, etc., becomes more imperative. Engineers have been and will continue to work in the direction of more uniformity in specifications for boilers. As the subject becomes more complex, we cannot expect of our consulting engineer that he be familiar with all the details of materials and workmanship involved. We are all compelled to become specialists in one way or another, and therefore to depend on other specialists. When these matters can be and, in fact, must be referred to a board with the power to act, and which can get the advice of the best specialists all over the country, we will have a basis for uniformity, which engineers must welcome. All work done by steel associations, boiler associations, and engineering societies in this direction has necessarily been simply educational. With the main facts readily accessible to those who want to or ought to know, what should be allowed to hinder the public conscience from getting itself enacted to a national boiler law.

An existing bureau whose work, though at present confined to navigable waters only, is necessarily coextensive with the entire Union, gives better promise of a successful solution of the matter as applied to land boilers than the creation of a new bureau from the ground up. And this, in my opinion, is the direction in which all who believe in a national boiler inspection law should work if they desire an early and complete accomplishment of the end.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XVIII. | MAY, 1897. | NO. 5.

MOLE ANTONELLIANA.

An Example of Light Construction in Brickwork.

BY G. W. PERCY, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, February 5, 1897.*]

THE city of Turin, Italy, possesses a structure which is without doubt the loftiest building in Europe and the most venturesome piece of construction in the world.

This is the "Mole Antonelliana," so called by general consent in honor of the venerable and skillful architect who conceived the project and personally superintended every part of the construction, with the greatest care and watchfulness.

The peculiarity of this remarkable work consists, principally, in its light skeleton construction with common bricks and lime mortar,† whereby a small quantity of material, and that of the most common kind, is employed to enclose a large building and carry it, with safety and stability, to the unprecedented height of 538 feet above the ground.

* Manuscript received March 22, 1897.—Secretary, Ass'n of Eng. Socs.

† The bricks used throughout this building are the common bricks of Northern Italy, measuring 2½"x4¾"x9½" with a crushing strength of about 100 tons to the square foot. The mortar is made from lime slaked and buried in pits for a year or more, and used with a proper admixture of sharp sand; no cement whatever is used in the work. The actual load on most of the supporting members is about 15 tons per square foot, which must be largely increased at times by wind pressure.

The method of construction, and the novel application of brick masonry in structural forms adapted to metal or fibrous material, make this building a unique structure in differing radically from all former monuments of masonry.

A brief history of the origin, progress and changing uses of the building is as follows:

In 1862 the Israelitish University Society of Turin, in view of that city being the capital of United Italy, determined upon building an imposing structure which should serve at once as a grand synagogue, college and administration building.

A competition was instituted during that year among the architects of Italy to produce plans of a building that should satisfy their various requirements.

Many plans were submitted, but none were considered satisfactory for the purpose, and after much discussion Professor Antonelli, of Novara (a master of architecture and engineering, who was then over sixty-five years of age, and who had erected the lofty and notable dome over the cathedral at Novara), was employed in 1864 to plan and construct such a building as they required.

Under his advice and management the present structure was commenced and carried by the Jewish Society to a height of 240 feet from the ground, or about three-quarters of the height of the great square dome.

The plan as devised for the society consisted of a building 130 feet square, with a projection 18 feet by 36 feet on each flank, containing stairways to all the main floors, and a front portico, 16 feet by 90 feet, with steps to the principal floor.

A lofty basement all above ground was divided into two stories to accommodate the college and administrative department, while the grand synagogue was above.

This consisted of a clear lofty room, about 90 feet square, surrounded with columns—six on each side (counting corner columns each time); outside of these columns are the walls, distant about 15 feet, thus making an aisle or ambulatory all around. Above this ambulatory, at a height of 17 feet 6 inches, is a gallery designed for women (now changed to a grand loggia).

At a still greater height, just above the first offset, was designed a beautiful exterior gallery extending all around the base of the dome, with a colonnade of graceful granite columns.

As will appear later in this paper, the omission of this granite colonnade on economical grounds greatly added to the difficulties of construction of the dome.

There were also three interior galleries, the highest being 80 feet above the floor of the synagogue.

The dome itself was originally designed to be surmounted by a cupola about 100 feet in height, divided into three stories, as shown in Plate 1, taken from the *American Architect and Building News*.

As before stated, the building was commenced in 1864, and proceeded rapidly to the height indicated at X, Fig. 1. Before the base of the dome was reached the need of retrenchment in cost was apparent, and the architect was directed to omit the granite colonnade forming the exterior gallery below the springing of the dome. Notwithstanding this was designed to produce equilibrium on the arches below, Antonelli ingeniously overcame the difficulty and proceeded with the work.

When, in 1869, the structure had reached the height shown in Fig. 1, the funds being exhausted and the Jews frightened at the greatness and unusual boldnesss of the project, together with the discouraging fact that Rome and not Turin was to be the capital of Italy, work was abandoned, and the unfinished and unprotected structure was left exposed both outside and inside to the elements.

No sooner had the work ceased than reports were spread that the structure was defective and would soon crumble to dust.

The Municipality, which at the beginning had accorded a subsidy to the Jews toward its erection in proportion to that granted the Roman churches now called a council of men, expert in art and science, to deliberate on the subject.

These, after carefully examining the work, reported in writing, in March, 1871, that the building was safe and sound, and needed only a "hat and shirt" to protect it from wind and rain; that it needed the termination and covering of the dome and the adornment of the drum with an exterior gallery, since "without that the edifice would appear a disproportionate heap and an intolerably ugly deformity."

The cost up to this time had been about $120,000, and the architect estimated that $12,000 more would finish it as designed.

For some months nothing was done. The destruction of the cupola was suggested, but protested against. In 1872 the president of the Jewish Society proposed ceding it to the city, but a few days after the Jews held a meeting, at which they resolved on the finishing of the temple, provided the cupola was demolished. This the Municipality refused to permit, and after prolonged dis-

cussion the building was allowed to remain as it was for several years.

In 1877 the Jews sold the building to the city of Turin for $30,000—one-quarter of its cost—to be converted into a museum and dedicated to Victor Emmanuel II, and Antonelli was authorized to prepare for its transformation and completion. In the following year work was commenced on the great dome and the granite gallery at its base.

In the meantime Antonelli, with increasing confidence and assurance in his work, had projected a loftier design, which instead of 100 feet should place 268 feet of cupola and spire above the great dome, and make it the highest building in Europe.

The perfect stability of the work up to this point, and the assurance of the architect that this great height could be erected with safety, led those in charge to yield to his ambition, and under Antonelli's personal supervision the structure was carried up to the base of the crowning statue, when, on October 18, 1888, Antonelli died at the ripe old age of ninety years. His son, who had assisted him in the supervision of the entire work, was placed in charge of the building.

The crowning statue was erected in 1889, holding a glistening star, 538 feet above the pavement—the greatest height reached by any structure of masonry in Europe, and only exceeded by the Washington Monument in this country. (The tower of the Philadelphia City Hall is ten feet higher, but the upper 200 feet are of iron construction.)

The interior has hardly received its finishing touches. It will probably be dedicated for a museum in memory of Victor Emmanuel II, in 1898, at the time of the Turin Exhibition.

With this brief history of the structure, we will now attempt to analyze its parts and describe some of the peculiarities of its construction.

The building consists essentially of a square, 130 feet each way, with piers 17 feet 8½ inches on centers, showing eight piers on each side, or twenty-eight in all; at a distance of 17 feet 8½ inches inside of these are the centers of an inner range of piers, with six on each side, or twenty in all.

These forty-eight piers perform all the work of supporting the walls of the building, the great dome, and lofty cupola and spire.

There are on each flank of the structure three piers supporting projecting wings enclosing stairways, and on the main front six more piers supporting the massive granite columns of a great por-

tico. Also, in the basement and sub-basement stories, there are eight interior piers which support the floor arches up to the great square room.

Thus there are in all sixty-eight piers supporting all parts of this interesting structure. The foundations for these piers are laid in sand forty-five feet below the surface of the ground.

There is a sub-basement, 17 feet 8 inches deep, below the basement floor or pavement level, and at this point we see the commencement of light arched construction which is to form the principal characteristics of the building throughout. At this level the interior piers are about 4 feet by 4 feet, and the exterior piers about 4 feet by 6 feet.

Instead of massive walls to resist the earth pressure and support the exterior walls, thin segment arched walls are sprung from pier to pier, with convex side outward; these in turn are buttressed and strengthened by horizontal arches at mid-height of the sub-basement.

From the level of the pavement the outside walls are carried on flat arches from pier to pier, thus throwing all weights of walls, floor, and contents on the piers. The three floors that intervene between the sub-basement and great temple are carried on remarkably light arches, some of them over thirty feet span and less than three feet rise.

The loggia and gallery floors are also carried on very thin and light brick arches employed with the greatest freedom in every part of the work.

The external architectural features of the building consist, first, of a basement story treated as pedestals for the pilasters and columns above; then two orders of architecture consisting of brick pilasters over the main piers, with granite Corinthian capitals. The walls between the lower pilasters are ornamented with small granite columns in two stories, with windows in the central spaces. The second order has a high brick screen wall, with small granite columns all open to the loggias before mentioned.

Above the cornice of the second order is the roof of the side projections and the front portico, and an offset of about five feet all around to the base of the great external gallery, with its fine granite colonnade around the base of the dome. Over this gallery is another sloping offset of about five feet to the base of the great square dome.

This portion presents five large arches on each side, with ornamental pilasters and entablature, which forms the springing line of the great dome, about 150 feet above the ground.

The great dome itself, 100 feet square on the outside and 120 feet high, has its sides falling inward about 35 feet, forming a square at the top of about 30 feet; on this is erected a combination of cupolas and spire, with granite columns and brick piers, crowned with a statue 268 feet above the dome, or 538 feet above the pavement as shown on Plate 4.*

Of the architectural effect, grace, or proportions of this building we do not wish to criticise or praise, but to call attention to the difficult problem presented and the skill with which it was solved.

The problem before the architect was to poise on this inner and outer square of slender supports a great square dome which should have its thrusts self-contained, be of such light construction that it should not crush the supporting columns, and of suffi-
itself through the various stages of construction without interior
cient strength to carry a lofty cupola and spire, and to support
centering.

Antonelli found by experiments that bricks would lie in equilibrium on a bed of mortar at an inclination of thirty degrees with the horizontal. He therefore arranged the pitch of the dome so that the greatest inclination of the radius should not exceed thirty degrees. He allowed six feet for the entire thickness of the dome, and placed the inner line or shell directly over the inside line of columns.

The elements of the dome then become established as follows:

Interior side	88 feet.
Thickness	6 feet.
Exterior side	100 feet.
Interior radius	246 feet.
Exterior radius	252 feet.
Height of dome	120 feet.
Base of cupola at top of dome, inside..	16 feet.
Base of cupola at top of dome, outside.	30 feet.

(Small fractions of a foot omitted.)

With the inside shell of the dome over the inner line of columns, and the thickness six feet, with the columns 17 feet 8½ inches on centers, it is evident that the outer shell would be about one-third of the distance to the outer line of columns, and to properly support this and place the dome in equilibrium on the two ranges of columns was the first great difficulty encountered.

* Plates 4 and 5 are taken from an Italian publication, and represent the parts of the building. The figures are in metres.

This might be easily accomplished with strong metal beams extending from column to column, capable of supporting the load at any point, but it was Antonelli's purpose to use brick arches everywhere to support loads, using metal very sparingly and only as ties and keys, and thus we find him preparing for this great load in the following manner:

Over the granite capitals of the second story of columns and at a height of 75 feet above the ground parabolic arches are sprung from outer to inner columns, with metal tie rods and flat groined arches to form the ceiling of the loggia.

On these transverse parabolic arches, which it will be remembered are only the width of the columns and 17 feet $8\frac{1}{2}$ inches apart on centers, are sprung two elliptical, longitudinal arches, dividing the space between columns into thirds, the inner line of these arches destined to carry the outer shell of the dome and the outer arches to support the granite exterior gallery, which we now see was designed to load the parabolic arches symmetrically quite as much as for other use or ornament.

It was after these arches were turned and the base of the gallery built that the architect was required to abandon the granite gallery to save expense.

Probably no one realized, as did Antonelli, the importance of this gallery as a counterpoise to the weight thrown on the inner side of the arches, or the skill and care it would require to prevent the parabolic arches from being very unsymmetrically loaded, with resulting displacement.

We shall see, however, how ingeniously Antonelli overcame the difficulty and moved on to the construction of the great dome.

Considering these arches capable of carrying a portion of the load unequally distributed, he proceeded with the vertical supports of the dome, consisting of two orders of columns inside and square brick piers outside, with a blank wall to receive the roof of the gallery when it should be built (as seen in Fig. 2), and over what should be the roof of the exterior gallery he turned five great semicircular arches on each side, which were to form large clerestory windows to light the interior and form architecturally the drum or base of the dome.

We have now arrived at a height of 150 feet above the ground and at the springing line of the great dome, and here a peculiar construction commences, such as one might design in iron, but which few would think of executing in brick and lime mortar.

It was necessary that in order to place such a lofty structure as was designed on such slender supports it should be as light as

possible, elastic and strong. In metal or timber this would not be a difficult thing to do, but in masonry it required a departure from all former efforts, and to accomplish which consummate skill in design, exactness in calculations of forces and stress, and the greatest care in workmanship and selection of materials were required.

It will be remembered that the entire thickness allowed for the dome was six feet; an inner shell was necessary to form a ceiling surface, and an outer shell on which to lay the roof covering. These the architect made as thin as possible—only one-half a brick, or about five inches each. The real supporting members consist of vertical ribs placed directly over the main supporting columns, 17 feet $8\frac{1}{2}$ inches on centers. These ribs consist of an outer and inner member about 10 inches by 15 inches each, connected at intervals of about 12 feet with cross arches, upright and inverted, with an iron tie rod through each connection.

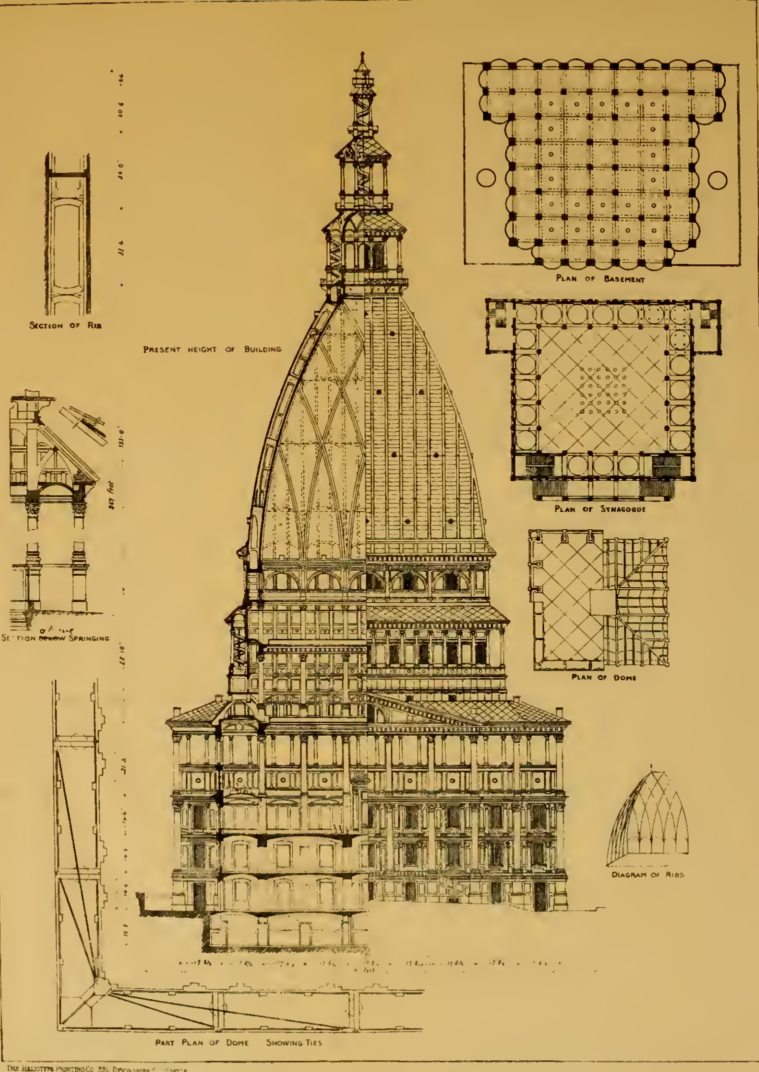
At each of the four corners are somewhat larger ribs or spines placed diagonally on the plan, constructed in a similar manner to the vertical ribs, and destined to carry the entire weight of the cupola and spire.

It will be seen by the sketches that the vertical ribs all join the corner spines in pairs, and their principal duty is to support the square dome, the two middle ribs on each side joining the angle spine at the top, where the base of the cupola rests.

The distance between the vertical ribs is divided into three parts by smaller ribs one brick square, through which iron rods pass about five feet apart, to secure the granite ribs on the outside of the stone covering.

The inside shell is also strengthened by similar small ribs projecting into the space between the shells, and further supported, while the entire structure is braced by curved ribs projecting with two offsets about ten inches on the inside of the dome. These curved ribs are struck with the same radius as the inside shell of the dome, and branch each way over every one of the interior columns, intersecting each other at acute angles and abutting, two by two, at the corners, thus dividing the interior surface of the dome into symmetrical panels with curved lines, and serving to distribute any weight or force acting on any of the spines to the several columns.

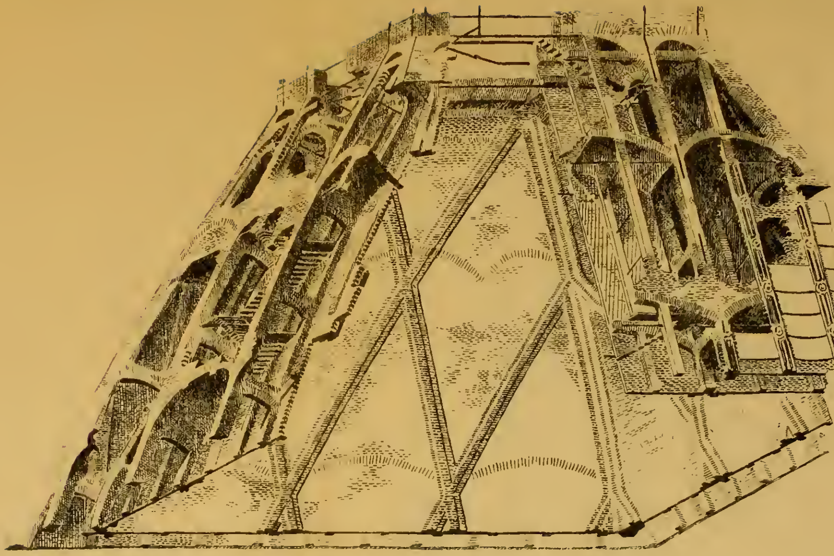
In building these curved ribs, some interior support may have been obtained by struts and braces from the timber scaffold which was erected inside the dome, but no complete system of centering was employed.



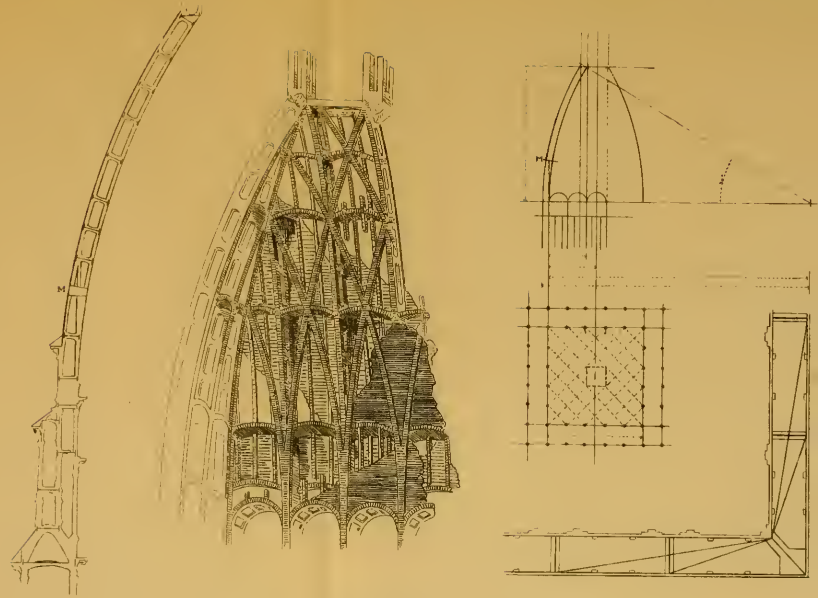
THE HELIOTYPE PRINTING CO. 220 DEVONSHIRE ST. BOSTON

MOLE ANTONELLIANA

PLATE 1.



MOLE ANTONELLIANA
Isometric View of Dome Construction
PLATE 2.



MOLE ANTONELLIANA
Details of Construction
PLATE 3.

The large panels between these curved ribs, only half a brick thick, are built slightly concave or sail-like, to prevent their falling inward while the mortar was still fresh. This concavity, however, is so slight it cannot be perceived from below.

At five different stages in the height of the dome horizontal arches are sprung from rib to rib, with thin arched floors spanning the space between shells and forming so many ambulatories around the entire dome, and making rigid connections of the various parts.

At the same time, wrought-iron ties are placed near these floors to resist any possible tensile strain that might come from the outward thrust or from the tendency to fall inward during construction.

Thus it will be seen the entire composition of this dome is a complicated piece of framing and trussing, with all the members in brick carefully proportioned to the work they have to perform, while iron ties are inserted only where tensile strain may be encountered.

As if the difficulties of carrying out this design were not sufficient, the necessity of omitting the external gallery required some device to throw more of the weight of the external shell on the inner columns than was first proposed, and thereby relieve the parabolic arches before described. This was accomplished, as is shown in Fig. 3, by carrying the inner member of the principal ribs in a vertical line to the point M, and there inserting granite blocks extending entirely through the dome, and by vertical piers above the granite, throwing the weight of the outer shell to the inside line.

This device proved successful, and no movement was apparent in the unequally loaded arches below.

Stone stairs are built into the space between the two shells of the dome, thus giving easy access to the cupola above.

This stage of the work was reached in 1880, and before proceeding farther the granite gallery so often referred to, and so much needed both to give symmetry to the building and equilibrium to the parabolic arches, was constructed; also the covering tiles were placed on the great dome. These consist of slabs of dense flagstone, about 2 inches thick and nearly 6 feet long, extending from center to center of the small brick ribs, while the vertical joints were covered and the whole secured with granite ribs carefully fitted to the slabs and held in place with iron bolts extending through granite and brickwork and keyed up on the inside.

A notable feature in all the iron connections throughout is that they are made in the old method of keys and wedges, instead of the more modern thread and nut. These bolts, placed at regular intervals and in horizontal rows about five feet apart, are formed with eyes on the outside, by which scaffolding may be secured.

One would suppose that when the top of the dome was reached, 275 feet from the ground, most architects would consider it desirable to finish the work with a cupola or lantern of moderate height; but not so with Antonelli. Not satisfied even with a three-story cupola, 100 feet high, which was first designed, he proposed the astonishing combination of cupolas and spire shown on the views of the finished building, and which required a further height of 268 feet and a superimposed weight of about 550 tons.

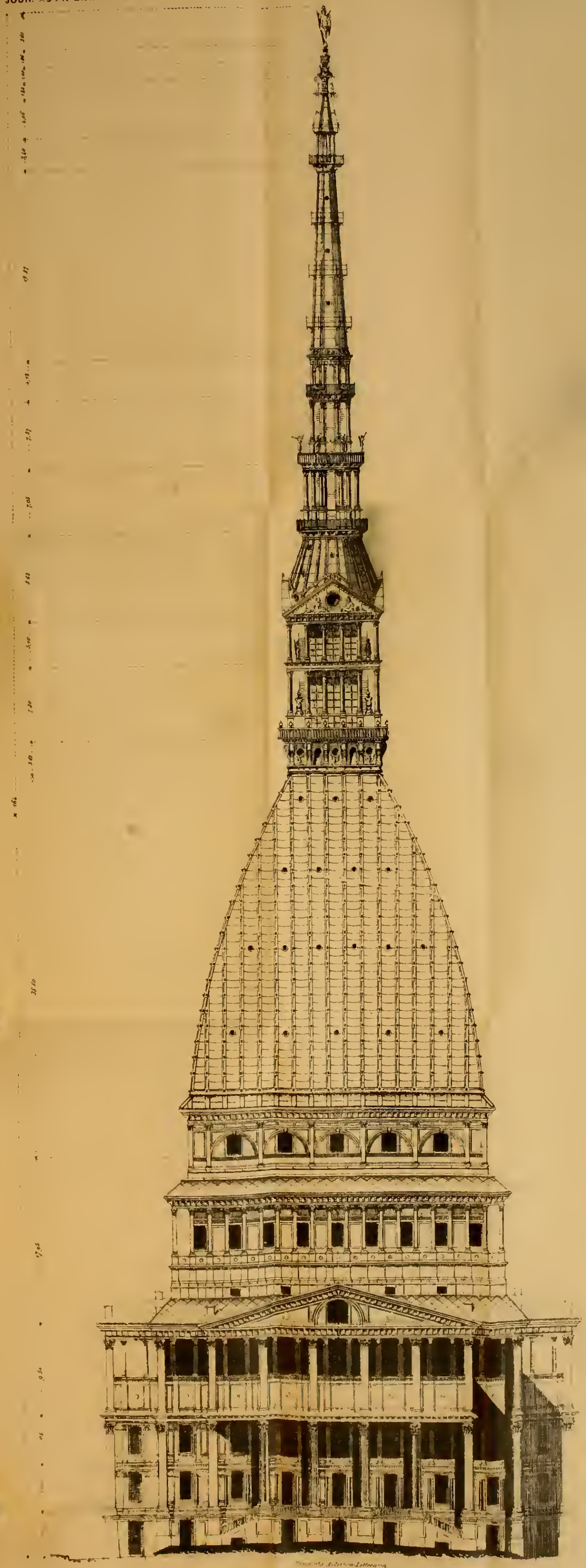
By this time we should be prepared for any venture the bold architect might make, and while we may be amazed at the slender construction placed at this great height and poised on such delicate supports, we shall find nothing more surprising than that we have examined.

As before stated, the converging ribs and spines meet at the top of the dome in such a manner that when connected with strong arches and iron ties they form a platform 30 feet square on the outside, with an opening 16 feet square in the center and the arches so constructed that all weight placed on this platform will be conveyed to the angle spines and distributed by the straight and curved ribs to all the columns below.

The base of the cupola, about ten feet high, is formed with six bracket-like piers on each side placed over the outside arches, and four piers on each side over the inside arches. The brackets on the outside support a granite balcony, from which a superb view of the city and surrounding country is obtained. Above this base are high pedestals, and two stories of granite columns on the outside line, and brick pilasters with windows on the inside, with all connecting arches of brick.

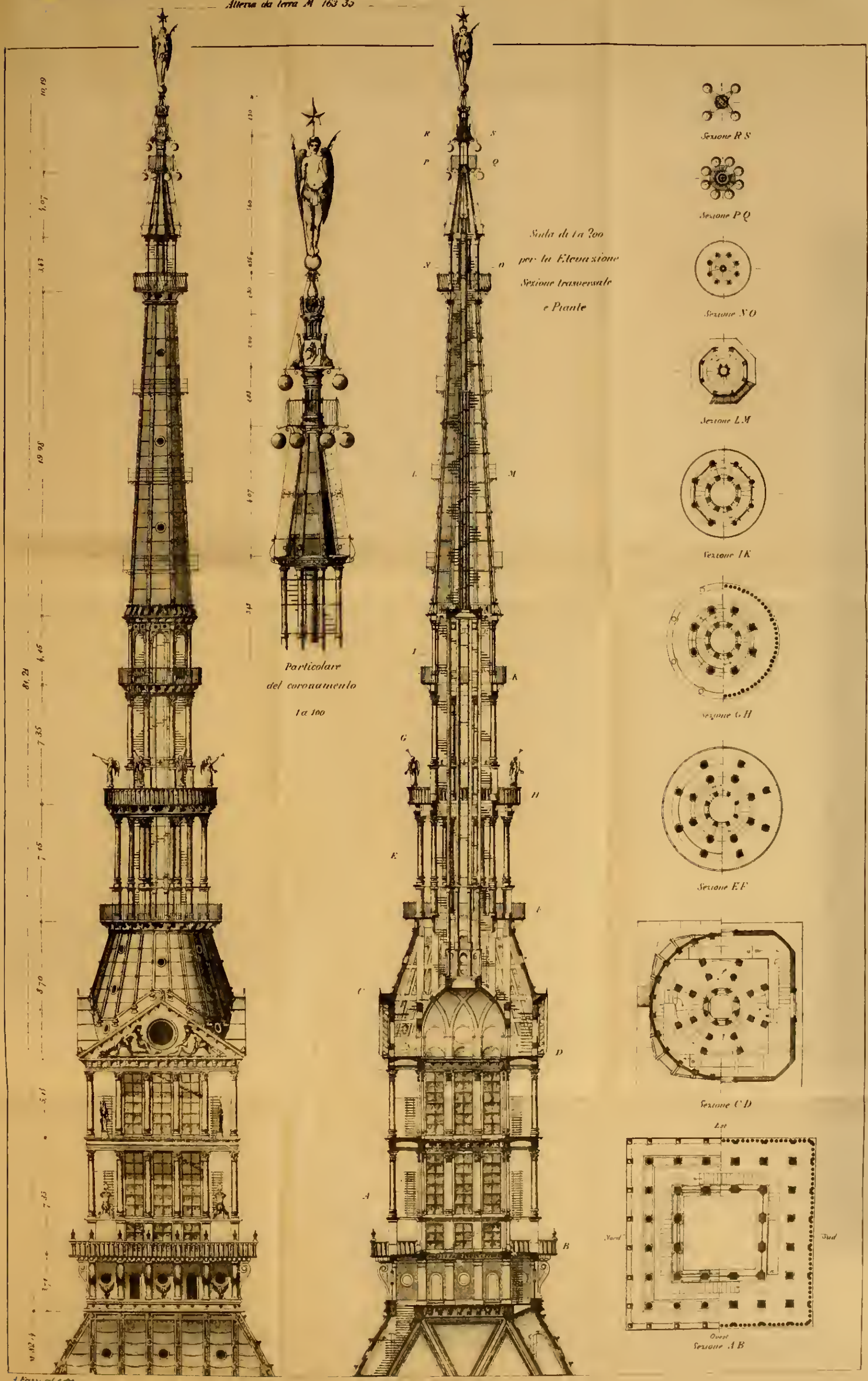
This lower section of the cupola terminates with stone pediments on each of the four sides and a conical-shaped roof above falling in about five feet, and consisting of a thin shell, one-half brick in thickness, stiffened with ribs and girts of a whole brick on the inside.

The top of this conical roof carries us 75 feet above the dome, and here the structure assumes a circular plan, with an outer and inner row of small granite columns, and inside of these another



MOLE ANTONELLIANA

PLATE 4.



MOLE ANTONELLIANA

PLATE 5.

circle of very small brick columns, between which and the inner circle of stone columns are double flights of winding stairs of stone.

The outer circle of columns are but one story high, and support another outside balcony, crowned in the design with eight angels, presumably blowing the last trump.

The inner circle of stone columns now become the outer ones, and extend two stories higher, with the stairs and inner columns as before described. And now, at a height of 135 feet above the dome, a slender spire is built for a height of 65 feet, consisting of eight brick piers, about 10 inches by 10 inches, forming the angles and connected with the stone roofing slabs, held with stone ribs on the outside, bolted through the angle piers, and braced on the inside by the stone stairs. The inner circle of brick columns has now become very small, with only about sixteen inches of a well-hole in the center. The stone stairs, now reduced to a single flight, continue to wind around the central shaft of brick-work, and reaches another stone balcony 205 feet above the top of the dome, or 475 feet above the pavement, the highest point to which the public is admitted.

Again we are treated to a story of stone columns, tied together with iron bands, the central hollow shaft of brick, and the stone winding stairs to the last open balcony that may be reached by stairs.

As the exterior diameter is here reduced to six feet, the stairs are no longer practicable, and those who would reach the higher balcony must ascend an iron ladder on the outside of the slender spire.

The finial and crowning statue is still elongated, as if determined to get as far as possible from the earth, and the whole is very appropriately surmounted with a star, which we hope will remain a fixed star for many years.

THE ENGINEERING VALUE OF MAGNETIC SURVEYS.

By Wm. S. Aldrich, Member of the Association of Engineers of Virginia.

[Abstract of paper presented at the Annual Meeting of the Association, January 30, 1897.*]

Successful engineering practice must be founded upon data determined by the exact measurements of modern science. The present paper presents matter of interest and importance relating to the bearing of magnetic observations on engineering developments. Little systematic work in any of our States has been carried on heretofore in the establishment of magnetic meridians and determination of magnetic data. The recent progress of this work in the State of Maryland calls for more than passing notice. It has been carried on under the direction of the State Geological and Economic Survey.

It would seem possible for the several affiliated branches of our Association of Engineering Societies to take up such matters with a view to Legislative enactments in their respective or adjoining States. In any case, it is especially desirable to bring to the attention of our members the great scientific and engineering value of such work. As our Association is represented in the principal cities and States, from the Atlantic to the Pacific, its interest in such work, once aroused, would no doubt encourage others to push forward the prosecution of magnetic surveys across this belt of our continent.

Primarily, a magnetic survey involves the scientific determination, at certain selected important points and at a given time, of the following so-called magnetic elements:

The magnetic declination or, as commonly called in surveying and marine work, the variation of the compass,—measuring the horizontal angle between the true geographical and the magnetic meridians at any point.

The magnetic inclination or dip of the magnetic needle,—measuring the vertical angle in plane of magnetic meridian which the freely suspended needle makes with the horizontal plane at that point.

The intensity of the earth's magnetic force at point of observa-

*Manuscript received May 9, 1897.—Secretry, Ass'n of Eng. Socs.

tion,—determined either, (a) in its total intensity, or (b) by its horizontal component.

At selected points throughout each State reliable data are thereby obtained for plotting on the map the following lines showing the characteristic features of the magnetic elements at the time of observation.

Isogonic lines drawn through all points having the same magnetic declination or variation of the compass.

Isoclinic lines drawn through all points having the same magnetic inclination or dip of the magnetic needle.

Isodynamic lines drawn through all points having the same—(a) total magnetic intensity, or (b) horizontal component of the earth's magnetic force.

The United States Coast and Geodetic Survey has obtained such data as to enable it to plot the general direction of these magnetic lines at the principal points of observation throughout the United States corresponding to particular epochs or periods of time. Such work has not been so consecutive nor so correlated as to make it of practical engineering value in each of our several States. It has been carried on largely in connection with their other work of triangulation and of topographical survey; and magnetic determinations were made at many such points as were established for these other surveys.

It has been general rather than specific. In no case has it been carried on systematically throughout any one of the States for distinctly promoting its industrial prosperity or engineering development. Such detailed work by government has been left to the respective Geological and Economic Surveys of the several States, if not to individual enterprise.

In Iowa, Missouri, Pennsylvania and New Jersey, magnetic observations have been made at a few isolated points by surveyors and other interested parties. Such data have related almost entirely to the declination of the compass needle, to re-establish the lines of old surveys at such time.

The most extensive and systematic work of this character has been inaugurated by the State of Maryland. Many of the early stations of the United States Coast and Geodetic Survey have been re-occupied, and magnetic survey stations have been established at every county town throughout the State, making forty-three in all. There is thus one station for about every two hundred and fifty square miles.

At those Maryland stations at which magnetic observations were made during the summer and autumn of 1896, such complete

data have been obtained as will prove to be of immediate value to all surveyors. It has been also sufficient to indicate its great scientific importance in connection with investigations connected with the location of the great rock masses in the State of Maryland.

The practical benefit to all land surveyors and other interested parties of such accurate magnetic determinations cannot be overestimated. They will prove of inestimable value to the County Commissioners of each State, enabling them to establish satisfactorily magnetic lines at each of the county seats. In several of the States the magnetic meridian is that to which all surveys are required to refer. At every county seat these meridians should be accurately determined, permanently located and periodically reestablished.

The lines of the old surveys cannot be satisfactorily retraced without such scientific data as those furnished by magnetic surveys. The disputes and losses arising from endeavors to retract old surveys, particularly in relation to valuable mineral and timber lands, would alone warrant a complete magnetic survey of the State. In many of the States such work is imperatively required, as well to settle legal questions on the one hand as to develop the State's resources on the other.

Magnetic determinations of this character have far-reaching importance. They bear upon all future observations and determinations affecting the magnetic conditions of the earth's crust. Such observations have been proven to be of the greatest geological value. The development of a State's mineral resources means the promotion of her material prosperity.

The problem of the nature and origin of "local disturbances" and their relation to geological formations require such scientific investigation of the terrestrial magnetic forces in all their components.

In connection with such magnetic surveys it is usually possible to carry on quite a number of other scientific observations, such as those looking to the determination of the force of gravity. Along with these are usually prosecuted certain economic investigations in well-known lines, looking to the production of suitable maps and reports. These set forth the physical features of the State, and show their practical bearing upon the development of its resources, the promotion of its industries and the advancement of its material prosperity, having due regard to the varying resources, conditions and needs of the several portions of the State.

ENGINEERING AS A LEARNED PROFESSION.

By D. C. Humphreys.

[Presidential Address at the annual meeting of the Association of Engineers of Virginia, at Roanoke, Va., January 30, 1897.*]

The formation of Engineering Societies is, of itself, a recognition of the community of interest that exists between us, and our object in meeting together is to promote the general interests of our profession, and for each to enjoy the fellowship of those who can best sympathize with him.

It is not necessary to prove to this body that engineering is a learned profession, for each knows well enough how much study and labor is necessary to properly qualify any one to practice any branch of our calling. What we want is that our profession should take equal rank with the time-honored professions of divinity, law and medicine. We would like to stand well in public esteem, for in that way only can we hope for adequate compensation, financial and social. In the higher walks of the profession, as in bridging the Mississippi or the English Channel, in tunnelling under the Alps or the Rocky Mountains, in constructing ocean greyhounds or battle ships, or in the harnessing of Niagara to the wheels of Buffalo, there is no lack of appreciation on the part of the public or of financiers. In such matters the predictions of the engineer are trusted as though he were at least "the son of a prophet." In railroading the public confides in us, as is testified by thousands who travel without giving anxious thought as to their safety; but railway managers do not always appreciate the importance of the civil engineer, and, not unfrequently, when a railway gets into the hands of the courts, the receiver cuts off the civil engineers as a means of cutting down expense. The same thing is sometimes done to prevent a road from going into the hands of a receiver. For instance, in 1893 I was told that one of the largest railway systems in the United States had discharged every civil engineer except the chief, in order to cut down expenses until times should improve.

As an illustration of the money value put on the services of an engineer, as compared with those of a lawyer, I will quote from an address, before the Perdue Society of Civil Engineers, by Mr. W. F. Goodhue, on "The Importance of Business Wisdom in an Engineer." Mr. Goodhue says:

---

*Manuscript received May 9, 1897.—Secretary, Ass'n of Eng. Socs.

"About twenty years ago a railway in Illinois became insolvent, and a receiver was appointed to take charge of its affairs. To reduce expenses, the receiver began by reducing the number of employees, and the first to go, as usual in such cases, was the engineer and all his tribe. For a number of years the road was operated in a cheap, haphazard sort of a way, when it was sold to an Eastern syndicate, who took immediate steps for reorganization, and I was appointed engineer in charge to rebuild the road. My first work was to thoroughly inspect the entire property and determine what was immediately necessary to make it safe for traffic, and also remunerative. I found that the roadbed, bridges, buildings, etc., had deteriorated beyond redemption, that the whole line must be rebuilt. At this time the road had been for about five years in the hands of a receiver, a lawyer.

"I labored hard and faithfully for six years, putting the entire road and its branches into first-class condition, and under its excellent management it has so remained to this day. For my services I received about $12,000. The lawyer remained with the road some years longer than I did. When it passed out of the hands of the master-in-chancery, by which act the office of receiver was abolished, the court ordered that the lawyer be paid, from the proceeds of the sale of the road, the sum of $125,000."

Then Mr. Goodhue goes on to say:

"Now, I do not cite this as a disparagement to lawyers, but as an example of the generally recognized value of a lawyer's services."

This case may be somewhat exaggerated, but most of us probably know of similar cases, where an engineer did most of the work and a lawyer got most of the pay.

However it may be in large affairs, when it comes to smaller ones, as the construction and maintenance of county roads, it is usually considered as not worth while to have an engineer at all. If we but look around us here in Virginia we will see that the mountain roads are for the most part admirably located because their location was difficult and the services of an expert were secured, whereas we find the location of roads in the open country in most cases faulty and frequently very bad, either because no engineer has been employed, or because he was required to follow land lines so closely that he was no longer a free agent. The community should employ a professional engineer who has to sustain, not only his own reputation, but that of his profession—a man who knows that one bad job is a lasting monument to his incom-

petence or dishonesty—and then give that engineer authority to make the best location, all things considered.

As an example showing how bad locations sometimes come to be made, I will cite a case in my own experience. I was once laying off some land, near a town, which had been sold by a development company to Mr. N., who, seeing how I was about to locate a road line, disappeared, and shortly came back with a written order from the president of the company to me, requesting that I so locate the new road line that a certain fence would not have to be moved. Mr. N. remarked, as he handed me the order, that he knew it was no use to talk to an engineer, for he would just follow his instrument and locate the road in what he thought to be the best place, regardless of the nice new fence. Under the circumstances I felt constrained to locate the road where both the buyer and the seller wanted it to be.

If the importance of having a competent engineer to locate and supervise the construction of highways and bridges was properly appreciated, we would have in every large county a county engineer who would be as highly esteemed as the County Surveyor was in pioneer days. Such a man might combine architecture with his other work, and leave his impress on the community in a more lasting way than the lawyer, the doctor, or even the preacher.

If our profession, as a whole, was properly appreciated, Governors, Mayors and Courts would uniformly appoint at least one engineer on each commission having anything to do with public works.

The doctors have found it necessary to adopt and enforce very strict rules of professional etiquette, and, in order to determine who is a doctor, they have invoked the aid of the State, which now refuses license to the ignorant and incompetent.

We might imitate them, to our advantage, but in the matter of State aid we are as yet hardly in a position to ask the State to say who is an engineer when scarce two of us would agree where to draw the line. The conditions are different with us and with the doctors. Our clients are, as a rule, business men, capable of taking care of themselves, and our mistakes are published "on the house tops" (or in the newspapers), while the clients of the doctor are frequently weak and incapable of judging of his qualifications, and the mistakes of that profession are buried or hidden.

Before we ask State aid, we must establish beyond question our right to be classed as a learned profession, and find, by natural selection, our place in the esteem of our fellows. When we have

done that, we may ask the State to recognize the existing status and to pass laws to prevent the incompetent, who call themselves engineers, from profiting by the hard-earned reputation of the profession.

That we may be esteemed learned, it is necessary that those following the profession should be learned.

The engineering colleges of this country are, for the most part, well equipped and are attended by more students than can make a living by strictly practicing the profession of engineering. This does not mean that young men are wasting their time, and their parents their money, in useless education, for there is in many of life's callings a demand for men with an engineering education, but it does mean that we can hope for a picked body of young men, who, by natural fitness or extraordinary industry, succeed in maintaining themselves in the profession, provided it pays them, financially or socially, to stay in it. By paying socially, I mean that a successful engineer should possess the consciousness of being useful in his day and generation, that he should have the fact of his usefulness recognized by society, and that he should be looked up to.

Now, in order that these young men entering the profession may be thought worthy to rank among the learned, it is necessary that they should first be liberally educated before they specialize. Indeed, herein lies, in my opinion, the distinction between a man with a trade and one with a profession. That one has special training without a liberal education, while the other has built the superstructure of specialization on the broad foundation of liberal culture.

Our profession may be defined as the art of using the forces of nature to satisfy the wants and promote the comfort of man. To make use of nature's forces one must first understand nature's laws, and a man is surely liberally educated who has anything like a comprehensive grasp of the way in which nature works.

To refer again to the medical profession, it is well established that a man should not adopt any specialty, as that of an oculist, for instance, until he is, by education at least, qualified to be a general practitioner. So I would say in regard to the specialties in engineering. The man who would be a successful electrical engineer, for instance, should first be a general practitioner, for in no other way can he get a proper perspective of any enterprise as a whole, and an adequate knowledge of the proper co-ordination of his part. To get a proper perspective of industrial undertakings and to be capable of advising capitalists or communities in regard to any

proposed work, it is necessary that the engineer should have a wide horizon. He must not only be acquainted with the physical laws of nature, but must know what we call human nature. Herein lies the explanation of the fact that the first-honor man at college is frequently, in fact usually, distanced in after-life by the all-round man who studies fairly well, and who, at the same time, knows how to dance, to skate, to play foot-ball and to make himself agreeable to the young ladies as well as to his fellow-students. Both these men are sometimes surpassed by the man who has never had a college education, for the latter, in his efforts at self-education, never finds a stopping place, while the college man is apt to think himself educated when he receives his diploma.

The advantage is with the college man, however, for he is like the man who has taken time to grind his axe before going to the woods, while the other is like the man who starts with a dull axe, and who is lucky, indeed, if he finds time to sharpen it, though he may have cut many trees before the other gets started.

Since the standing of our profession depends largely on the amount and quality of the education given those who enter it, I will briefly outline what I think that education should be.

The prospective engineer should, if possible, have a primitive workshop at home, and should learn early to be a tool-using animal; he should receive a good all-round training at a good high school or fitting school, with some manual training; he should receive a liberal education at college, strengthening weak points, so that he may have symmetrical development, but at the same time he may begin the special studies that are to be the basis of his life work. At college he should study English and some other language, say one modern language as a minimum, but his main work should be in science, studying the properties of materials and the fundamental principles of engineering structures, so that he may be rendered capable of reading practically all engineering literature. He should have in the chemical, physical and engineering laboratories enough work to enable him to understand his theoretical studies, and to give him confidence in himself and in his ability to put at least some theory into practice. This laboratory work should include a summer course in surveying and geology. At the end of a four years' course, if worthy, he should receive the degree of Bachelor of Science, which should mean that he is liberally educated, especially in those branches of science likely to be of most use to an engineer.

I believe this part of his training can be most efficiently accomplished at an institution where he will meet with young men who

expect to go into the other learned professions, those of divinity, law and medicine. Contact with these will help greatly in making a man of him.

After this he should either go to some rich engineering college, elaborately equipped, not only for experimental work, but for research as well, or else he should go to work wherever he can.

At the end of a two-years' course at such a graduate college, or university, he should receive the professional degree of Civil Engineer. There are strong reasons for giving also the degree of Mining Engineer, Mechanical Engineer, Electrical Engineer, etc., but the trouble is to know where to stop, and the tendency is, therefore, to simplify degrees by making them less numerous.

It would be well for college graduates and, I believe, also for the various great industries if others would do as the General Electric Company has done. It has opened an expert department in its shops, where college graduates are admitted and given a chance to become thoroughly acquainted with the company's machinery. These apprentices test the ordinary machines, and are changed from one class of work to another. At the end of a prescribed course, if such a young man has made good use of his opportunities, he is an electrical engineer, and may be sent to any part of the world to erect and install plants; or, if he sets up in business, he has a strong bias in favor of the apparatus that he knows to be good as against that of other make which, nevertheless, may have many points of excellence.

In railway shops, shipyards and elsewhere such a department of expert apprentices might be established with great advantage to the industry, and appointments need not be confined to college men, but also offered as a reward to bright men in any department. The engineering college would, on its part, meet the move half way and offer scholarships to some deserving apprentices who may show themselves worthy of higher education.

The six-years' course here prescribed would place the full engineering graduate where he should be—viz: on the same educational plane with the Ph.D. and ahead of the lawyer, the doctor and the preacher.

MUNICIPAL LIGHTING IN THE UNITED STATES.

By F. W. Cappelen, Member Am. Soc. C. E.

[Read at the meeting of Engineers' Club of Minneapolis, Minn., November 16, 1896.*]

At the second annual convention of the American Society of Municipal Improvements, held in October last year, at Cincinnati, Ohio, a committee on electric street lighting, consisting of Mr. John A. Cabot, Chief Electrician B. of A., Cincinnati; Harold P. Brown, Consulting Electrical Engineer, Newark, N. J., and myself, was appointed.

We divided the entire United States into three sections, and, with Canada added to my portion, correspondence was entered into with the various cities.

The accompanying question sheet, after first being formulated and agreed upon by the committee, was sent out:—

1. Names of companies furnishing lights.
2. Life of Contract: From....189.. to....189..
3. No. of 2,000 C.P. Arc Lamps in operation.
4. No. of miles of streets lighted by same.
5. Cost of same per night....or per year.
6. No. of 1,200 C.P. Arc Lamps in operation.
7. No. of miles of streets lighted by same.
8. Cost of same per night....or per year.
9. No. of 16 C.P. Incandescent Lamps in operation.
10. No. of miles of streets lighted by same.
11. Cost of same per night....or per year.
12. No. of 32 C.P. Incandescent Lamps in operation.
13. No. of miles of streets lighted by same.
14. Cost of same per night....or per year.
15. No. of 50 C.P. Incandescent Lamps in operation.
16. No. of miles of streets lighted by same.
17. Cost of same per night....or per year.
18. No. of 100 C.P. Incandescent Lamps in operation.
19. No. of miles of streets lighted by same.
20. Cost of same per night....or per year.
21. No. of Gas Lamps in operation.
22. No. of miles of streets lighted by same.
23. Cost of same per year....per 1,000 cubic feet.
24. Electric Schedule: All night....Moonlight....Until Midnight Special. Gas Schedule: All night....Moonlight....Until Midnight....Special.
25. What Arc Lighting System used.
26. How is C.P. of Arc Lights determined.
27. Is Arc Light Contract based upon electrical consumption of lamp.

*Manuscript received April 9, 1897.—Secretary, Ass'n of Eng. Socs.

28. What contract provision for testing C.P., or current and voltage.
29. What contract penalty for shortage.
30. Iron or Wooden Lamp Poles used.
31. At what height above the street are Arc Lamps supported.
32. How are Lamps supported. Fixed on Poles....On Mast-arms Lower from Span Wires.
33. Arc Lamp Poles owned by City or Company.
34. What Arc Lamps used: Single Carbon....Double Carbon.
35. What Carbons used: Round....Elliptical.
36. Arc System: High Tension....Low Tension....Alternating.
37. What, if any, limit upon number of Arc Lamps per Circuit.
38. Globes in use: Plain....Ground....Opal.
39. No. of Arc Lamps: On Overhead Circuits....On Underground Circuits.
40. What Insulation Resistance Tests on Circuits.
41. Are Pole Lines owned by the City or the Company.
42. Are Conduits owned by the City or the Company.
43. Name or Character of Conduit in use.
44. Miles of Conduit in use.
45. Miles of Duct in use.
46. What Annual Rate paid City for Pole Lines or Conduits.
47. What Incandescent Lamps are used.
48. What System of Operating Incandescent Lamps....: Low Tension....High Tension....Alternating.
49. How is the C.P. of Incandescent Lamp determined.
50. What Contract Provision for testing same.
51. What Contract Penalty for Shortage.
52. How are Incandescent Lamps supported.
53. How high above street.
54. No. of Incandescent Lamps on Overhead Circuit....on Underground Circuit.
55. Does City own the Electric Lighting Plant.
56. If owned by City—Cost of Electric Light Machinery.
57. Cost of Steam Power Plant.
58. Cost of Water Power Plant.
59. Cost of Pole Lines and Wire.
60. Cost of Underground Construction and Wires.
61. How are Outages reported.
62. What Deductions are made from bill when Outages occur.
63. Character and Horse power Engines used.
64. Character and Horse power Boiler used.
65. Kind of Fuel used.
66. How are Parks lighted.

It is certainly most complete, embracing sixty-six questions pertaining to street lighting. One thousand eight hundred and ninety-seven letters were sent out, and 171 cities replied. The committee reported at the convention in Chicago last month, but as it was impossible for the members of the committee to come together to formulate the report, this was made rather short, and,

at my suggestion, all answers received were tabulated on tracing cloth, giving the result of our labor.

Since the Chicago meeting I have spent considerable time in studying these tables, and will now give you the benefit of the work, including the Chicago report.

The total population of 171 cities tabulated is 6,654,096.

There are 187 companies furnishing electric light in these 171 cities.

Life of contract varies from one to twenty-five years. Davenport, Iowa, has a twenty-five year contract.

Springfield, Ill., has a contract to furnish light until the city purchases a plant.

Number of miles of streets lighted by arc lamps, 4,537.

Number of miles of streets lighted by incandescent lamps, 356½.

These tabulated sheets show 30,802 arc lamps of 2,000-candle power and 11,572 of 1,200-candle power in operation, and incandescent lamps as follows: 7,026 of 16-candle power, 4,718 of 32-candle power, 251 of 50-candle power, 530 of 100-candle power.

The cost of arc lighting with 2,000- and 1,200-candle power lamps averages as follows in the various states:—

	2000. PER LAMP PER YEAR.	1200. PER LAMP PER YEAR.
Alabama	$109.50	
Arkansas	140.00	
Arizona	41.27	
California	129.50	
Colorado	128.00	
Connecticut	86.60	$86.20
Florida	90.00	60.00
Georgia	85.00	
Illinois	69.07	36.00
Indiana	69.10	64.25
Iowa	79.91	
Kansas	91.84	
Louisiana	90.00	
Maine	45.00	
Massachusetts	148.80	90.60
Michigan	81.80	67.50
Minnesota	124.60	
Missouri	75.00	37.78
Montana		168.00
Nebraska	109.33	44.28
New Hampshire	90.00	75.00
New York	83.00	100.00
Ohio	75.38	

	2000. PER LAMP PER YEAR.	1200. PER LAMP PER YEAR.
Pennsylvania	$90.00	
Tennessee	94.00	
Texas	100.00	$74.16
Vermont	78.00	65.00
Virginia	65.70	
West Virginia	90.00	
Wisconsin	93.00	76.25
Washington	110.93	
Wyoming	162.00	

Thirty-one states with an average of $94.21 per lamp of 2,000-candle power per year.

Fourteen states with an average of $74.67 per lamp of 1,200-candle power per year.

The average cost in 51 cities for a 2,000-candle power on all-night schedule is $93.00. For a 2,000-candle power lamp in 57 cities on the moonlight schedule the average is $89.98.

For 1,200-candle power lamp all night, 14 cities, the average is $100.00, and

For 1,200-candle power lamp on the moonlight schedule in 15 cities, $68.20.

The cheapest all-night lighting is in Kendalville, Ind., where it is done by the city for $30.00 per year for 2,000-candle power lamp. Next comes Bangor, Me., for $45.00, also by the city. Rockford, Ill., pays $52.00 on a five-year contract. In Tacoma, Wash., lighting done by the city cost $100.00, which is the highest amount paid where the city owns the plant.

Cheyenne, Wyo., pays $162.00, which is the highest sum paid when lighting is done by contract.

Minneapolis pays $150.00 for the all-night lamp.

Thus, according to the tabulated information presented, there is only one city that pays more for an all-night 2,000-candle power lamp than Minneapolis, and this is Cheyenne, Wyo.

The average cost for 2,000-candle power lamp, all-night service, when done by contract, is $106.85 (29 cities). The average cost for 2,000-candle power lamp, all-night service, when done by the city, is $66.26 (9 cities).

The average cost, moonlight schedule, when done by contract, is $95.70 (24 cities); when done by the city, is $56.67 (9 cities).

The cheapest by city is $41.27, Prescott, Arizona.

The highest by city is $74.16, Fort Worth, Texas.

The cheapest by contract is $50.00, Oberlin, Ohio.

The highest by contract, $180.00, Pine Bluff, Arkansas.

The following cities are furnished 2,000-candle power lamps by their respective street railway companies on all-night service:—

Lynchburg, Va., for $65.70.

Milwaukee, Wis., $92.00 to $109.00.

Ashland, Wis., $132.00.

1,200-CANDLE POWER LAMP AVERAGES.

Average for 14 states, as before stated, $74.67.

Average cost in 14 cities, all-night service, $100.00.

Average cost in 15 cities, moonlight service, $68.20.

The cheapest all-night service by contract is $65.00, Ludington, Mich.

The highest all-night service by contract is $180.00, New York City.

The average all-night service by contract is $100.00.

Reading, Mass., is the only city that runs its own plant on all-night service for $65.00.

The cheapest moonlight service by contract is $36.00, Canton, Ill.

The highest moonlight service by contract is $90.00, Marlborough, Mass.

The average moonlight service by contract is $73.00.

The cheapest arc, only one service, by city, is $37.78, Savannah, Mo.

Menominee, Mich., is furnished by the street railway company for $70.00, all-night service.

It may be of particular interest to you to know that in New York City the electric lighting is entirely done by 1,200-candle power lamps, with the exception of 68 16-candle power incandescent lamps, lighting three miles, at $25.00 per annum.

1,682 lamps at the rate of 40 cents per night.
924 lamps at the rate of 45 cents per night.
154 lamps at the rate of 50 cents per night, or about $180.00 per year.
496 lamps at the rate of $125.00 per year.

Total 3,256, lighting 165 miles of street.

Brooklyn has 3,134 1,200-candle power lamps, lighting 120 miles, at $127.75 per lamp. There are several companies and one-year contract in both cities.

The following cities own their own plants:—

Place.	No. Lamps.	Candle Power.	Schedule.	Cost per Year.	Cost of Plant.	Cost of Plant per Lamp.
Prescott, Arizona	209	2000	Moonlight	$41.27	$35,000.00	$169.00
S. Norwalk, Conn.	100	2000	Moonlight	60.22	14,000.00	140.00
Jacksonville, Fla.	100	2000	All night	90.00	86,000.00	*701.00
Bloomington, Ill.	300	2000	Moonlight	60.00	83,000.00	277.00
Champaign, Ill.	72	2000	Moonlight	64.30		
La Salle, Ill	98	2000	Moonlight	46.00	12,400.00	126.00
Ottawa, Ill.	133	2000	All night	57.50		
Kendalville, Ind.	60	2000	All night	30.00	8,000.00	133.00
Topeka, Kansas	184	2000	Moonlight	56.21	47,000.00	255.00
Bangor, Maine	152	2000	All night	45.00	§35,000.00	230.00
Reading, Mass.	158	1200	All night & S.	65.00	35,000.00	221.00
Bay City, Mich.	181	2000	All night	49.17	32,674.00	180.00
Detroit, Mich.	1472	2000	All night	84.70	408,680.00	274.00
Savannah, Mo.	26	1200	S.	37.78	12,000.00	461.00
St. Joseph, Mo.	333	2000	Moonlight	66.00	92,000.00	276.00
Dunkirk, N. Y.	75	2000	Moonlight	45.50	21,000.00	280.00
Fredonia, N. Y.	58	2000	Moonlight	42.00		
Hamilton, O.	216	2000	All night	75.00	100,000.00	463.00
Marietta, O.	112	2000	All night		18,000.00	†160.00
Martins Ferry, O.	100	2000	Moonlight		21,000.00	210.00
Tacoma, Wash.	700	2000	All night	100.00		
Fort Worth, Texas	68	2000	Moonlight	74.16	44,000.00	‡647.00

*Also provides for 320, 32 C.P. incandescent lamps.

†New.

‡Also provides for 400, 32 C. P. incandescent lamps.

§Water.

The average cost of plant per lamp for 2,000-candle power lamp is $282.00.

Two years ago I made plans and estimate for a 1,000-lamp, 2,000-candle power plant for the city of Minneapolis, the estimated cost, $300,000, including everything, or, per lamp, $300.00.

The estimated cost of one lamp per year was $78.00, which is $12.00 more than the average cost given previously. It must, of course, always be remembered that where a city does its own lighting, no taxes are derived as in case a corporation has a lighting contract, so a certain percentage should be at least mentally considered when comparisons are made.

INCANDESCENT LIGHTING.

Some twenty cities use incandescent lights, partly alone and partly with arc lighting.

Jacksonville, Fla., has 320 32-candle power lamps, all night, at $15.00 per year, and Fort Worth, Texas, has 396 32-candle power lamps, moonlight, at $9.27 per year. These two cities own their own plants. The average price is about $20.00 per year for 32-candle power lamps.

Seattle has 666 15-candle power lamps, for 50 miles of street, at $21.60 for all-night service.

Pittsburg, Kan., has 800 16-candle power lamps at $9.60, all-night service.

St. Louis, Mo., has 3,094 30-candle power lamps from $17.20 to $26.00, all-night service.

STREET LIGHTING.

The street lighting, as it is done to-day in the following large cities, is of interest:—

New York has 3,256 1,200-candle power arc lamps at $125 to $180 per year, lighting 165 miles of street.

New York has 68 16-candle power incandescent lamps at $25.00 per year, lighting three miles of street.

New York has 25,453 gas and naphtha lamps at $12.00 to $28.00 per year, lighting 457 miles of street. One-year contract. Total, 625 miles.

Brooklyn has 3,134 1,200-candle power arc lamps at $127.75 per year, lighting 120 miles of street.

Brooklyn has 13,851 gas lamps at from $18.25 to $28.00 per year, lighting 150 miles of street. One-year contract. Total, 270 miles.

St. Louis has 2,241 2,000-candle power lamps at $74.95, 400 miles; 3,094 30-candle power incandescent, $17.20 to $26.00, 137.66 miles; 1,054 gas lamps at $37.00, 31.91 miles. Nine-year contract. Total, 569.57 miles.

Philadelphia has 6,361 2,000-candle power lamps at $128.04, 129 square miles; 17,808 gas lamps, of which now 13,626 are lighted free by the city (whole city lighted). One-year contract for electric lights. The city owns the gas plant.

Chicago has 37,846 gas lamps, 11,309 gasoline lamps, 194 oil lamps, 1,611 2,000-candle power electric lamps, at a total cost of $1,022,545.69, lighting somewhat over 1,000 miles of its streets.

Chicago operates and owns about 1,100 arc lamps itself. Chicago is not in the report, as no information could be obtained. The above statistics I have taken from the 1895 municipal reports of Chicago.

$4,288,207.19 is the total amount expended for arc lighting.

$180,450.32 is the total amount expended for incandescent lighting.

This tabulated report shows that 81 cities use the all-night schedule, 23 the moonlight, 22 midnight, and 25 special.

The following arc systems are used:—

Axnoux	1	Shuyler	5
Helious	1	Standard	6
Remington	1	Westinghouse	7
Wagner	1	Western Electric	8
Van de Pole	1	Fort Wayne	10
Siemens & Halske	1	Wood	14
Edison	3	Brush	20
American	3	Thomson-Houston	27

The following incandescent lamps are used:—

Sawyer-Man	1	Warren & Columbian	1
Davis	1	Bernstein	4
Twing	1	Th.-H	5
Diamond	1	Edison	14
Sunbeam	11		

The following engines are used:—

Corliss	21	Armington & Sims	1
Ideal	3	Rice	1
Automatic	4	Mackintosh & Seymour	1
Russel	7	Westinghouse	3
Buckeye	4	Taylor	1
High Speed	7	Davis & Thompson	1
Triples	3	Dick & Church	1
Ball	4	Fraser & Chalmers	1

Twenty-nine cities report no method of determining the candle power of arc lights, and 53 report as having a method, but do not explain it.

There are 86 cities that base their arc light contracts on the lamp, and three on electrical consumption.

Only 37 cities have a contract provision for testing candle power.

Only 18 cities have a contract penalty for shortage.

Eighteen use iron and 146 use wooden poles.

Arc lights are supported at heights that vary from 8 to 50 feet. Only one city 8 feet; most have 25 to 30 feet.

Four towns have arc lights supported on towers from 125 feet to 175 feet.

Sixty-eight cities support arc lights on poles.

Sixty-five cities on mast arms and 117 lowered from span wires.

Sixty-two cities use the single and 108 the double carbon lamps.

Ninety-two cities use the high, 14 the low tension, and 17 alternating arc lamps.

Circuits carry various numbers of lamps, ranging from 25 as a minimum to 125 as the maximum.

There are 128 cities using plain, 28 ground, and 8 opal globes.

Springfield, Ill., gets 25 cents per pole.

Davenport, Iowa, 50 cents per pole.

Fort Madison, Iowa, $2\frac{1}{4}$ cents per pole.

Rockford owns the pole line, and gets 30 cents per pair of wires on each pole.

Philadelphia receives $1.00 per pole per annum and $300 per annum for first mile of conduit, $250.00 per annum for second mile of conduit, and $200 for each fraction and mile over two miles.

Outages are reported in 68 cities by the police, in 17 by citizens, in 10 by inspectors and trimmers, and 6 have no system of reporting.

One hundred and thirty-four cities use round carbon and 15 "elliptical."

The total expense of lighting these 159 towns and cities amounts to $4,468,657.51. Chicago not included.

Twelve cities do not give cost of lighting.

Minimum cost for lighting (arc), $600.00 per year, Idaho Springs, Col.

Maximum cost of lighting (arc) per year, $486,444, New York City.

Minimum cost of lighting (incandescent), $18.00, Montpelier, Vt., one lamp of 32-candle power.

Maximum cost of lighting (incandescent), $66,830, St. Louis, Mo.

Minimum cost of light per year, $864.00, Nebraska City, Neb., arc and incandescent lamps.

Maximum cost of light per year, $488,144, New York City, arc and incandescent lamps.

The smallest town heard from was Savannah, Mo., with a population of 1,288.

The largest, New York, with a population of 1,515,301, census of 1890.

One of the most interesting cases (before referred to) is the city of Springfield, Ill. As the city was indebted to the legal limit and unable to raise funds sufficient without incurring further debt, and wished to own its own plant for lighting, the Mayor made an agreement with a syndicate of local capitalists, the latter to build the plant, the city to pay for the arc lamps $113.33 per annum, moonlight schedule.

The difference between $133.33 and $60.00 is to be applied to the future purchase of the plant by the city. The item of $60.00 is the price agreed upon as the maximum cost of procuring one arc lamp per year, the syndicate to furnish the current, free of cost, of 450 16-candle power lamps, alternating incandescent, for

lighting the public buildings of the city, the city in turn furnishing the syndicate water free of cost, for steam purposes. The syndicate also does an extensive commercial business, both arc and incandescent. The city is supposed to receive 25 per cent. of the gross receipts of this business, to be applied toward the purchase of the plant.

The following suggestions might be made as to the best method of street lighting:—

For densely populated cities and districts, two lamps in series, placed side by side on 110 volts incandescent circuit, "conduit work" is probably the most desirable. For sparsely settled districts, the series system with aerial lines is most economical and satisfactory. All arc lighting ought to be done in continuous current. The maximum number of arcs on a string is 200, as this would give about 10,000 volts. From point of economy and as an ideal plant, the slow speed (130 revolutions) engine, with dynamos running from shaft, would be recommended.

For good results, and next best to recommend, would be a pair of arc machines, connected to a high speed engine, giving a total number of arcs of 400.

Conduit work should be used only where it is absolutely necessary, as trouble is caused continually from short circuiting.

The trouble with cable work in conduits is that, in the first place, the highest degree of insulation must be adopted to prevent leakage and danger from this source. This high method of insulation necessarily creates another danger, to-wit: the creation of electrostatic charges, which is liable to destroy the cable and interfere with the service, and the fact is that to-day nothing is absolutely safe.

Concentric paper cables have the least electrostatic capacity, but even then a great deal of trouble is caused from puncturing. It is a well-known fact that in the underground work in London, where cables are suspended in the tunnels, punctures are caused by rats smelling the cable. The rat is killed.

The London Deptford Station has to be shut down quite frequently on account of trouble of this sort.

I personally believe that the best conduit has not as yet been made, but that when Mr. Ransom, of Chicago, perfects his idea of making the conduit in one body of concrete, as he is making ducts for carrying water and sewage, I believe that his will be the nearest to perfection.

Not being an expert in electricity, I simply advance the above ideas from knowledge and information that I have been able to obtain upon the subject.

ARTIFICIAL LIGHTING.

By George D. Shepardson, M.E., Member of the Engineers' Club of Minneapolis.

[Read before the Club, December 29, 1896.*]

Part I.—Outline of the History of Lighting.

The subject of artificial lighting is one whose importance to any nation or people is commensurate with their civilization. The savage may retire with the fading daylight, but with civilization comes the desire to prolong the hours of business and of social enjoyment. The production of a satisfactory light is a problem of universal importance, and the business of supplying light is one of enormous magnitude. England alone[1] requires eleven million tons of coal annually for the manufacture of illuminating gas, and the annual exports of mineral oil from the United States amount to more than fifty million dollars. The rapid development of electrical science and industries is largely a result of the demand for better and cheaper light. Conversely, the recognized advantages of arc and of incandescent lamps have greatly stimulated rival methods of illumination.

Artificial lighting is of great antiquity. A number of passages in the Bible indicate an early acquaintance with candles and lamps. Genesis[2] contains an account of Abram (cir. 1913, B. C.) seeing a smoking furnace and a burning lamp. Candles are mentioned several times in Job. The tabernacle[3] (cir. 1491, B. C.) contained an elaborate candlestick with seven lamps[4] burning pure olive oil. Herodotus[5] (cir. 450, B. C.) describes Egyptian lamps having wicks floating in vessels filled with olive oil and salt. The Greeks[6] and Romans used tallow and wax candles with rush wicks. Their early lamps were of unglazed pottery with one hole for the wick of flax-tow or rushes. Sometimes these lamps were of highly ornamented metal, having from one to twelve wicks. In the time of Homer[7] (cir. 1000, B. C.) lighted torches were used for nocturnal excursions. Lanterns and torches were carried[8] by the Jews and Romans who arrested the Saviour. Elaborate lanterns with horn chimneys were owned by the Romans. Their torches[9] were ropes

*Manuscript received May 7, 1897.—Secretary Ass'n of Eng. Socs.

[1] Am. Gas Light Jour., LX; 618, Apr. 30, 1894.

[2] Gen. XV: 17.

[3] Exodus XXV: 31.

[4] Ex. XXVII: 20.

[5] Herod. II: 62.

[6] Smith Dict. G. & R. Antiq. 236.

[7] Dict. G. & R. Antiq. 236.

[8] John XVIII: 3.

[9] Fosbroke Enc. Antiq. I: 323, 469.

impregnated with inflammable materials. Ptolemy built a lighthouse[10] at Pharos, the site of Alexandria, Egypt, about 300, B. C., with a tower 450 feet high surmounted by a fire of burning wood that could be seen for forty-two miles. At an early date the streets of Antioch were lighted at night, and probably those of Rome also.

After the fall of the Roman Empire, little progress was made until near the close of the eighteenth century. Public lighting of streets seems to have been abandoned until about 1770, A. D., when lanterns containing oil lamps[11] were used in some of the streets of Paris, the first modern city to adopt this means of diminishing the frequency of robbery and murder.

Until about 1780, the candle and the ancient oil lamp with round wick were the only means[12] of artificial lighting. In 1783 Leger used a flat wick instead of a round one. The marked improvement in the combustion and brilliancy of its light led Argand[13] to carry the idea further. About 1784, he brought out his cylindrical burner in which the combustion of the oil was improved by the central draught. This seems to mark the distinction between ancient and modern lighting. In 1803, Carcel brought out a lamp with clockwork for feeding heavy oils by pressure, thus enabling the use of heavy vegetable oils. The "moderator" lamp of Franchot, in 1836, was much stronger than any of its predecessors.

Petroleum in different forms has been known and used since the earliest days of the human race. From time immemorial it has been used in China[14] for lighting towns near oil springs and deep wells. The ruins of Nineveh and Babylon attest the accuracy of the account in Genesis xi: 3, that slime (asphalt) was used (cir. 2350, B. C.) as mortar in large edifices. The account in Job xxix: 6, mentions "the rock pouring out rivers of oil." Near the Caspian Sea, oil springs have been flowing for certainly more than 2500 years.[15] At a temple of the Parsee fireworshippers near Baku on the Caspian Sea, a bluish flame has burned continuously for centuries without human care, the gas coming from natural sources. Herodotus[16] (cir. 450, B. C.) mentions that liquid bitumen was found on Zacynthus, one of the Ionian Islands. This was one ingredient of the much feared Greek fire. Pliny (23-79,

[10]Knight Dict., Mech., *Lighthouse.*
[11]Sci. Am. Supp., No. 877, p. 14011.
[12]Sci. Am. Supp., No. 877.
[13]Chamb. Cyc., *Lamps.*
[14]Knight Dict. Mech., p. 943.
[15]Chamb. Cyc., *Baku.*
[16]Amer. Cyc., *Baku;* Herod. I, 119; II, 195; Amer. Cyc., *Petroleum.*

A. D.), and Dioscorides[17] (cir. 150, A. D.?) state that at Agrigentum in Sicily, the oil floating upon the water of a spring was collected upon reeds and burned in lamps, and used for horse liniment. Petroleum has been collected on the surface of certain wells in the northern part of Italy since 1640. Natural gas was used[18] at Wigan, Great Britain, in 1667.

Petroleum has been found in America since prehistoric times. Indisputable evidence[19] shows that certain oil springs in Pennsylvania, Ohio and Canada were opened 500 to 1000 years ago. The first written account[20] of an oil spring in America was by a French missionary who visited, in July, 1627, the one at what is now Cuba, Allegany county, New York. The Seneca Indians skimmed the oil from the surface of a large pool and used it as a liniment. Later this was sold to the whites as "Seneca oil," "rock oil," or "coal oil." Considerable oil was obtained[21] from a well dug near Marietta, Ohio, in 1819, and was used locally for lighting. The disagreeable odor caused it to be considered a nuisance rather than a valuable commodity. Flowing springs and wells were found in West Virginia at an early date. The town of Fredonia, in western New York, was illuminated by natural gas in 1821 and attracted great attention. About 1835 natural gas was found near Gambier, Ohio, where it has been used continuously for many years in the manufacture of lampblack. The petroleum business did not assume any considerable magnitude in America until 1860. In 1859, crude petroleum sold[22] at $20.00 a barrel. The following year the new wells in Northwestern Pennsylvania put 200,000 barrels upon the market, and the price fell to $10.00 per barrel, going down to 50 cents in April, 1861. In June, 1861, the first flowing well was struck and spouted 300 barrels per day. Soon a third well began spouting 3,000 barrels per day, and oil dropped to 10 cents per barrel, an empty barrel being worth fifteen times as much as the oil it would hold. In less than a year, 1,500,000 barrels of oil were produced along Oil Creek in Pennsylvania, more than half of it running to waste. Some wells yielded their owners $15,000 income per day. Prices fluctuated greatly and rapidly. Since 1869, the price has steadily dropped from $7.00 per barrel and, since 1878, has been below $2.00 per barrel, most of the time being

[17]Diosc. 1: 99. Knight Dict. Mech., p. 1673.
[18]Knight Dict., Mech., I: 943. [19]Chamb. Cyc., *Petroleum.*
[20]Ashburner, Trans. Am. Inst. Min. Eng., June, '87.
[21]S. P. Hildreth, Am. Jour. Sci., X: 5, 1826.
[22]Lebanon Gazette, Apr. 11, 1895.

below a dollar. Immense quantities of petroleum products are shipped from America, the export trade exceeding the home consumption. From 1864 to 1890, the petroleum exports[23] aggregated $1,043,474,435; 664,500,000 gallons of mineral oil were exported in 1890, with a valuation of $51,403,000.

Outside of the United States the principal petroleum fields are in Burmah and near the Caspian Sea. The latter regions were taken from Persia by Russia in 1806,[24] but were not developed until 1872, after Russian engineers had been sent to America to investigate our methods. Upon their return the fields about Baku were rapidly opened, and the number of wells increased from one in 1871 to 400 in 1883. The production in 1885 was 420,000,000 gallons of crude oil.

When petroleum and its numerous derivatives became cheap enough for ordinary lighting, various forms of burner were invented. The flat and Argand burners, previously used for animal and vegetable oils, were easily adapted for kerosene. The modified Argand burner of the student lamp and the more recent and powerful "Electric" and "Rochester" burners are sufficiently familiar. Numerous forms of burner are extensively employed for lighting with gasolene and naphtha. All of the latter heat the liquid and convert it into vapor before burning. After the vapor has been generated, it may be burned with almost any form of tip suitable for ordinary gas. In the common form of plate burner, the vapor issues from a needle-pointed orifice and strikes a curved plate, which spreads it out into a flat flame.

Although natural gas is generally found in connection with oil wells, it was not developed extensively until 1882, when large gas wells were struck in western Pennsylvania, followed soon after by New York, Ohio, West Virginia and Indiana. The gas commonly had a pressure of 100 to 325[25] pounds per square inch, in one instance rising as high as 750 pounds. The natural gas caused the rapid growth of many towns and revolutionized several industries, being found much more economical and more easily managed than any other form of fuel. While the pressure is diminishing in many places, the supply promises to last for years.

Artificial gas was first distilled[26] from coal in 1688 by Dr. Clayton, of England. In 1750 Bishop Watson conveyed gas in pipes to some distance. In 1792 a Mr. Murdock lighted his house and office at Redruth, Cornwall, England, with coal gas. In 1798 he

[23] Chamb. Cyc., *Petroleum.*

[24] Chamb. Cyc., *Baku.*

[25] Sci. Am. Supp., No. 549, p. 8765.

[26] Knight Dict., Mech., p. 944.

lighted some shops at Soho. In 1802 M. Lebon[27] lighted his own house and proposed to light the streets of Paris. In 1803 one of the theatres of London was lighted by gas. About 1807, Pall Mall in London was lighted. English Parliament chartered the first gas company in 1810. The first large installation of street gas lights was in 1813 on the Westminster bridge in London. In 1815 the streets of Paris and London were lighted by gas. Baltimore in 1816, Boston in 1820, and New York in 1825 were the first American cities to adopt gas.

The earliest type of gas burner was the "cockspur" with three jets which gave long and unstable flames affected by the slightest atmospheric movement. The batswing burner[28] having a slit aperture and giving a flat fan-like flame, was introduced about 1816. The fishtail burner, with two orifices at an angle of 60° so that the jets cross and flatten, was invented about 1822. These burners gave a much more steady flame, besides being more efficient. Later improvements have increased the efficiency of the fishtail burner from 1.66 to 3.09 candle power per cubic foot of gas burned per hour, while the batswing has improved from 3.01 to 4.0 candles. The efficiency varies greatly with the adjustment and the pressure. For every form of burner there is one pressure at which it will yield greatest economy. In a given case, a fishtail burner gave 3 candle power per cubic foot with gas at a pressure of 0.5 inches of water, but only 1.11 candle power at 3.0 inches pressure. Between 80 and 90 per cent. of the burners used in England are of the ordinary type of brass-cased fishtails.

The Argand burner, brought out in 1784 for oil lamps, has been used for gas with many modifications. It gives more light than flat flame burners using the same amount of gas, but has the disadvantage of requiring a glass chimney. A number of regenerative or recuperative gas lamps have been invented with a view to increasing the efficiency of the flame, by heating the gas or the air or both before combustion. The principal burners of this type were by Siemens,[29] Wenham[29] and Schulke.[30] The relative efficiencies of these burners[31] is, that with equal rate of burning gas, a flat flame burner gives 14 candle power, Argand 17, Schulke about 30, Wenham 35, and Siemens about 40 candle power.

---

[27]Knight Cyc. Arts and Sci., IV, 303. Fosbroke Enc. Antiq., I, 469.

[28]Knight Dict., Mech., *Gas Burner,* 946. Bellamy, Am. Gas Light Jour, LX: 619.

[29]Jour. Fkln. Inst., CXVIII: 298, Oct., 1884. Sci. Am. Supp., Nos. 219 and 301.

[30]Sci. Am. Supp., Nos. 454 and 482.

[31]W. J. Dibkin, Am. Gas Lt. Jour., LX: 624, Apr. 30, 1894.

In order to appreciate the reasons for the next development, it is necessary to consider the real source of the light of the candle, oil lamp and the common forms of gas burner. The flame is a column of heated gases which carry off by convection 80 per cent.[32] or more of the heat of combustion. The flame owes its luminosity to the comparatively few particles of unoxidized carbon near the burner that are heated to incandescence by the combustion of the remaining portion. If combustion were perfect, the flame would be non-luminous, as with the Bunsen burner. The flame makes an inefficient furnace and the incandescent particles utilize only a very small fraction of the total amount of heat. Of the energy radiated by these particles, only a small part is of such wave-length as to affect the organ of vision and give light. If the net efficiency be taken as the ratio of the luminous energy radiated to the total energy consumed, the net efficiency of an oil or gas light varies from 0.1 to 0.3 per cent.

The recent progress in gas lighting is in obtaining complete combustion of the gas, and heating to a high temperature some incandescing substance. The most familiar of these is the calcium[33] or Drummond light, in which a point in a lime cylinder is heated white hot by an oxyhydrogen flame, or by compressed oxygen and illuminating gas. After the invention of the Bunsen burner, many experimenters attempted to use it for lighting. In 1881, Clamond[34] heated a basket of magnesia to incandescence with a Bunsen burner. The basket was too short-lived. In 1882, Victor Popp heated a basket of platinum in a similar way. In 1883, Somzee[35] obtained a bright white light from a perforated capsule of lime or porous magnesia coated with zirconia. In 1883, Fahnehjelm[36] heated combs of magnesia rods held in an arch above a flat non-luminous flame of water gas. The combs lasted from 80 to 150 hours. This was used to a considerable extent in America. In 1890, Fahnehjelm made his pencils more durable by mixing magnesia with oxides of chromium, wolfram, manganese, cobalt, nickel or copper, singly or mixed. In 1891, Haitinger used alumina and oxide of chromium or of manganese, intimately mixed mechanically and subjected to a high temperature. This gave a bright warm reddish-yellow light. In 1893, Hirshfield[37] used a basket of sulphate of alumina and chromium oxide.

[32]E. L. Nichols, El. Eng., X: 595. Elec. World, XVI: 387, 409.
[33]Sci. Am. Supp., Nos. 281 and 328.
[34]Sci. Am. Supp., No. 561. [35]Sci. Am. Supp., No. 561.
[36]Sci. Am. Supp., No. 493. Trans. Am. Inst. Min. Eng., Feb., 1885.
[37]Progressive Age, XII: 498.

The Welsbach burner[38] seems to be the highest type of incandescent gas lamp. Carl Auer von Welsbach, a student of Professor Bunsen, at the University of Heidelberg, became interested in illumination in 1880. His mantle burner is the result. He used a mantle knit from fine cotton thread into a cylinder. This was saturated in a solution of the salts of lanthanum, zirconium and yttrium. The cotton was then burned away, leaving a fragile skeleton or basket of the minerals. Auer's first English patent was applied for[39] in 1885. The next year he obtained another patent for using thorium oxide alone or with alumina. The thoria lengthened the life of the mantle and increased the amount of light by 20 to 30 per cent. Large numbers of these burners were placed upon the market in Europe and America. In this country they soon lost favor and disappeared. About 1892, an improved Welsbach burner came out and is now meeting with great success, immense numbers being sold. The principal improvement is in the mantle. The cotton mantle is saturated[40] in a solution of 98 per cent. of thoria and 2 per cent. of cerium. After the cotton has been burned away, the basket is dipped in a weak solution of caoutchouc or collodion, in order to withstand transportation. This mantle is suspended over a Bunsen burner and becomes highly incandescent, giving a steady column of white light about 3 inches high and 1 inch in diameter. These give over 60 candle power with a consumption of about 2.5 cubic feet of gas per hour.

The development of the electric light is so recent and is so well known, that little time need be taken to outline it. The discovery of the arc light is usually attributed to Sir Humphry Davy, who made a public exhibition of it in 1809. There is evidence that E. G. Robertson[41] publicly exhibited an arc light formed between carbon points in March, 1802. It is also claimed that Davy had first discovered the arc in 1800.

The development of the arc and of the incandescent lamp was somewhat slow on account of the great cost of primary batteries which were then the only available source of electricity. In 1838, M. Jobard, of Brussels,[42] published a description of an incandescent lamp having a carbon conductor in a vacuum. In 1844, Foucault, of Paris, made a hand-regulated arc lamp, and the next year Wright,[43] of England, patented an arc lamp fed by clockwork.

[38]Jour. Fkln. Inst., CXXV: 379-387, May, 1888.

[39]Sci. Am. Supp., No. 606.

[40]Progressive Age, XII: 408.

[41]Elec. World, XX: 163.

[42]La Lumière Electrique, VI: 580. Dredge Elec. Illumination, I: 574.

[43]Dredge, I: 380.

Moses G. Farmer lighted his residence at Salem, Mass.,[44] by incandescent electric lamps every evening during July, 1859. The dynamo electric machine had gradually been developing since Faraday's discovery in 1831, and in 1857 a proposition was made by Professor Holmes to light some of the English lighthouses by arc lights operated by dynamos. After various delays, a plant was installed at Dungeness lighthouse,[45] and the arc light was first used for practical lighting, June 6, 1862. French lighthouses were soon similarly equipped. Various improvements in the lamps and machines were made. In 1878, the Avenue de l'Opera in Paris was lighted by arc lamps. In the same year, Chas. F. Brush[46] invented the differential arc lamp which made it possible to operate a number of arc lamps in series.

Sawyer, Man, Edison, and others had been working upon the incandescent lamp, and by 1880 Edison had a practical lamp. He soon began the construction of a central station, and on September 4, 1882, the Pearl Street Station began supplying current for commercial lighting by incandescent lamps.

Since that time the business has grown, until in 1896 there are in the United States 2,500 electric light stations, 200 municipal plants, and 7,500 isolated plants representing an invested capital of not less than $500,000,000. There are about 500,000 arc lamps in use, consuming 200,000,000 carbons annually, while from 50,000 to 75,000 incandescent lamps are made daily to supply necessary renewals and extensions.

The subject of artificial lighting is therefore one of vast importance and we will next give some attention to some of the underlying principles.

Part II.—Light and Lighting.

Light and lighting should be considered both from a physical and from a physiological standpoint. The sensation of light is the effect of vibrations of certain wave lengths upon a sensitive portion of some organism. So far as present purposes are concerned, it is their effect upon the eye of a person or animal. Objects are seen only as they send waves of light to an eye. They may emit various kinds of vibrations or waves and of widely differing wave lengths.

Vibrations which affect the human eye are of a limited range, the longest rays at the red end of the spectrum having a length of about 1 micron or 0.001 millimeter, and making about 300,000,-

[44]Pope, Evolution of Incandescent Light, p. 20.

[45]Dredge Elec. Ill., I: 124. [46]Elec. World, XXV: 260.

000,000,000 vibrations per second, while the short rays at the extreme lavender end of the spectrum have a wave length of 0.36 micron, or 0.00036 millimeter, and make about 800,000,000,000,000 vibrations per second. Rays of a much shorter wave length affect photographic plates, the ultra-violet photographic rays having a length of 0.185 micron, or 0.000185 millimeters. At the other end of the visible spectrum, heat rays may be found with wave lengths at least 30 microns, or 0.3 millimeter. The range of the human eye is therefore only about fifteen-thousandths of the range of the spectrum perceptible by photographic and calorimetric methods. Using a musical analogy, the human eye is sensitive through a range of only about one octave; that is, the longest waves have only about twice the length of the shortest waves affecting the eye.

The human ear is sensitive through a much wider range. The human voice has a range from the lowest "A" of the Jubilee Singers, with fifty-five vibrations per second, to the highest "A" of Yaw, with 1760 vibrations. The human ear is sensitive at the lower limit to sound vibrations having a frequency of 16 per second and a wave length of 21,350 millimeters, or 70 feet, and at the upper limit to sounds of about 50,000 vibrations with wave lengths of 7 millimeters, or about 0.27 inch. At present it is not possible to compare the eye and ear with reference to the range of intensity of perceptible stimulus, since the science of sound is not yet so far advanced as to have units and methods for measuring intensity. The range of the human ear from the faintest whisper of the telephone to the boom of a cannon is certainly very wide. But the human eye, by the combined adjustments of the retina and of the iris, can perceive lights of intensity varying[47] in the ratio of 1 to 1,000,000,000,000,000, or of 1 to 10^{15} That this is a reasonable figure is seen by the fact that a rash person will sometimes look directly at the sun for a few seconds, while on the other hand he may be able to see the light of a single candle on a dark, clear night at a distance of one mile or more.

While the human eye is able to perceive lights of so widely differing intensity, it must be remembered that two such lights cannot be seen at the same time, for both the iris and the retina adjust themselves for the strongest light in the field of vision. Various experimenters have found that one light becomes invisible in the presence of another when the ratio of their intensities is greater than from 1 :64 to 1 :190, the ratio varying according to the inten-

[47]Langley, "Philosophical Magazine," ser. v, vol. 27, p. 22.

sity of the stronger light. As examples of this may be cited the fact that the stars, which shine continuously, are invisible in the daytime unless one shields his eyes from the daylight. When one's eyes have been exposed to a strong light, some time is required for the iris and retina to adjust themselves to a comparatively weak light. For example, if one is coming in from the open air where the sun was shining on the snow, the interior of a well-lighted house seems quite dark for some seconds until the eye has accommodated itself to the less intense illumination; conversely, one is more or less blinded for some time when going out into the strong sunlight. The action of the iris, or curtain of the eye, in opening or closing to regulate the amount of light received is familiar to all, being most prominent in the eye of the common cat. The action of the retina is not so commonly understood. The parts of the retina are, as it were, stunned by the action of intense light, as shown by the transient rings of light frequently noticed after closing the eye or coming in from exposure to a strong light. A similar phenomenon is observed by looking steadily for a few seconds at the filament of an incandescent lamp, after which a bright image of the filament will remain in the eye for a considerable period. The varying sensitiveness of the retina is also noticed when coming into a comparatively dark room after being in a much stronger light; as time elapses the retina becomes more and more sensitive, so that objects at first invisible, or seen only in dim outline, become gradually more distinct in detail. After being exposed to very strong light, as much as an hour may be required before the eye becomes highly sensitive to feeble lights.

The energy of light is easily reducible to other forms of energy, most conveniently into heat. By means of the bolometer Professor S. P. Langley has investigated[48] the sensitiveness of the eye in different parts of the spectrum, and finds that the amount of light energy required to affect the eye so that one can distinguish whether a light is present or not, is almost inconceivably small. The following table gives part of his results:

Color.	Wave length (microns).	Reciprocal of ergs.	Horse-power.
Violet	0.40	1,500,000	0.000000000000000018000
Green	0.55	360,000,000	0.000000000000000000075
Scarlet	0.65	1,600,000	0.000000000000000017000
Crimson	0.78	780	0.000000000000034000000

This table suggests at once that the eye is much more sensitive

[48] "Phil. Mag.," ser. v, vol. 27, pp. 1-24. "La Lumière Electrique," vol. 30, p. 31.

to some wave lengths than others. Different sources of light give spectra of widely varying intensities. For example, ordinary gas light is largely composed of red, yellow and green rays, while the light at the violet end of the spectrum is comparatively weak. The light of the arc, on the other hand, is comparatively strong in the violet end of the spectrum. For the purpose of distinguishing colors, the composition of the artificial light should approach that of daylight as closely as possible, the ability to distinguish colors being largely dependent upon the character of the light.

The brightness of an object varies directly with the amount of light it receives and inversely with its distance from the eye. Objects are visible by sending light to the eye. When the object is not the primary source of light it is seen by reflected light. By the familiar law of optics the intensity of a light varies inversely as the square of the distance, since the area of a shadow varies thus. When the light goes to an eye and produces the sensation of light, the matter becomes more complicated. The area of the pupil of a normal human eye is about 0.7 square centimeter[49] when fully dilated. If the light is very strong, the iris contracts so that a smaller proportion of the light striking the exterior eye enters and affects the retina. The iris dilates as the light recedes and becomes less intense. After the iris has opened fully so that this diaphragmatic action no longer complicates matters, the amount of light striking the effective external surface of the eye varies in accordance with the familiar law of inverse square of the distance. But since the eye is an optical instrument, having a lens which focuses the image on the retina, and since, therefore, the image diminishes in size as the distance to the object increases, its brightness or intensity does not diminish inversely as the square of the distance, but more nearly as the simple distance. This is further complicated by the fact discovered by Fechner[50] that the sensation produced in the eye or brain is not simply proportional to the stimulus, but follows a logarithmic law.

The quantity of light emitted by a body is the product of the intensity by the area. For example, one bare arc and another arc enclosed in an opal globe might emit equal total amounts of light, the larger surface of the globe, which becomes the effective source of light, offsetting the greater intensity of the bare arc.

The time required for vision varies according to the color and intensity of the light and according to the complexity of the sub-

[49] Du Bois Reymond, "Nature," May 3, 1888, p. 15.

[50] Webber, "Science of Lighting," pp. 17-19.

ject. Mendenhall[51] found that the automatic action between brain and muscle took about 0.1 second. It took 0.443 second to decide between white and red; 0.494 second to decide between a triangle and a circle. Langley[52] found that it took from 0.507 to 0.242 second to decide whether a light was present or absent. Mendenhall found it took 0.293 second for a white card to appear and 0.203 second for an electric spark. The duration of the impression[53] varies with the color of the light, varying from 0.008 second with strong, yellowish, green light to about .06 second with weak, violet light. It follows that an intermittent light may give a continuous impression, as when one swings a light rapidly in a circle. But unless the impressions are oftener than 0.008 to 0.06 second, or 125 to 16 times per second, the eye perceives an unpleasant flicker. Consequently, with incandescent or arc lamps operated by alternating or pulsating currents, the specific heat and mass of the carbons helps reduce the variations. The lowest tolerable limit seems to be about 25 to 30 cycles per second for incandescents and about 40 for arcs. Experience with the Pennock "volt-distributor" shows that in some circumstances the frequency must be still higher. Pennock's scheme was to send current through ten or twenty sets of lamps by means of a revolving commutator, which should send current through one set at a time, the impulses being so frequent that no lamp would have time to cool off from one impulse of current until the next current heated it again. In this way the usefulness of the current was to be multiplied ten to twenty fold. By this means a small primary battery would light a large house or propel a ship across the ocean. Any one doubting this may visit the electrical engineering museum at the University of Minnesota and examine the original machine built by the Northwestern licensees, according to directions of the inventor, and later rescued from the wreck for educational purposes.

Having considered briefly some general truths concerning light and the eye, we may turn next to some practical applications. Artificial lighting may be classified under two general heads, according as it is desired to obtain illumination or illumination appearance; in other words, whether the objects illuminated by the lights, or whether the lights themselves are to be the principal center of attention. In many cases a combination of illumination with illumination appearance is desired, while, on the other, illum-

[51] "Amer. Jour. of Science," ser. 3, vol. 2, p. 156.
[52] "Philosophical Mag.," ser. 5, vol. 27, p. 22.
[53] Ferry, "Amer. Jour. Sci.," vol. 28, p. 243.

ination appearance is often obtained unintentionally and undesirably when illumination only is sought.

The principles involved in securing satisfactory illumination without illumination appearance are quite simple in the abstract, although not always recognized, and although sometimes difficult to apply in practice. The ideal is to keep the prime source of light unseen while the objects of vision are evenly and sufficiently lighted. As mentioned before, the eye accommodates itself to the strongest light in the field of vision, and consequently objects only moderately bright are less clearly seen. For example, an object in the direction of a window between the observer and the bright daylight is only seen in dim outline, and its details are meagre. The prime source of light, therefore, should not come within the field of vision.

For the ordinary human eye the field of vision is an irregular cone, having the eye at its apex, and whose edges make angles with the center line of about 60 degrees in the vertical plane and 80 degrees in the horizontal plane. These angles should be increased 15 to 30 degrees in each direction to allow freedom of motion of the eye and head. As the eye changes position frequently, the sources of light should be removed outside of a cone considerably larger than the field of vision, otherwise the eye would be continually adapting itself to widely different intensities of light and would soon tire.

Electric lights are peculiarly adapted to being placed high out of the range of vision. Incandescent lamps may be studded around the ceiling and along the border. Sometimes incandescent lamps are placed behind a translucent cove or above projecting cornices, so that the lamps themselves are invisible. A more common plan used with both arc and incandescent lamps is to have opaque reflectors below the lamps[54] so as to throw all the light up against the white ceiling, which becomes a secondary source of soft diffused light. Lamps thus arranged give an evenly diffused daylight effect that is very pleasing if sufficiently strong.

In large rooms with high ceilings gas fixtures are frequently placed well up out of the range of vision, when provided with electric spark lighting devices, and may be so arranged as to give satisfactory effects. It is far too common to have public halls lighted in such a way that the audience can hardly see the speaker without squinting between or under lights that blind more than illuminate.

[54]See articles by B. A. Dobson, "Lond. Electrician," vol. 31, p. 701, and vol. 32, p. 13; "N. Y. Elec. Engineer," vol. 16, pp. 513 and 548; "Cassier's Mag.," vol. 5, p. 417.

Doubtless the drowsiness that regularly creeps over some evening audiences is due less to the dullness of the speaker than to the stupidity of the architect or lighting designer. When the lights are necessarily so placed as to come within the angle of vision, they should be shielded by diffusing globes, which, while not cutting off too much of the total quantity of light, will spread it over a larger surface so that the apparent source of light may not be so intense. Another method of ameliorating the difficulty is to have the lights at full brightness only when the audience has occasion to read, and then to reduce the light when their attention is directed to the speaker. This plan saves eyes and reduces lighting bills.

Another essential for even illumination is to avoid regular reflection of light from the source to the eye. All surfaces reflect more or less light, polished surfaces reflecting regularly, so that a more or less perfect image of the light source may be seen upon the polished surface. Rough surfaces reflect the light irregularly, so that it is diffused and the light source may be seen reflected only vaguely. Hence the familiar rule that the light should come over one's shoulder. This is not always practicable, unless each person has an individual light screened from others.

For satisfactory general illumination, the light should come from a number of scattered sources rather than from one. Shadows are thereby avoided and objects stand out in better relief. Streaks of light and shadow from inequalities in the globes or fixtures are minimized by the mixture of light from many sources. Diffused daylight is the ideal illumination for most purposes, the light coming in all directions, everything being a secondary source of diffused light.

When the sources of light are necessarily few, or if they necessarily come within the range of vision, the effect is greatly improved by surrounding each source by an opal or holophane globe, which becomes the apparent source of light. While the globe absorbs more or less light, what remains is well diffused, and the larger area of the apparent source largely compensates for its less intensity. Regular reflection of such light from polished surfaces is less trying upon the eyes. Again, if the light comes within the direct angle of vision of the eye, it is so much less intense that the eye is more sensitive for other objects. It must be remembered that objects are visible by means of the diffused light coming from them to the eye. If a bright light is within the range of vision the iris and retina adapt themselves to the more intense light. Therefore, it follows that if a room be lighted at one time by a bare arc light and at another time by the same arc light surrounded by a

white globe, objects in the room are seen more distinctly when the light has a globe than when bare, the greater sensitiveness of the eye more than balancing the less amount of light. For the same reason Welsbach gas lamps are comfortable for reading purposes when shielded by opal globes, although the glare is distressing when the light issues directly from the incandescent mantle. Incandescent electric lamps also give a softer and more effective light if provided with opal globes when close to one's work.

A further condition of satisfactory illumination already hinted at, is to avoid great variations in different parts of the same area. The normal human eye was made for long distance work, and when used for close work, such as reading, it must be rested occasionally by brief glances toward more distant objects. If the illumination of the distant objects is widely different from that of the work, the eye tires from frequently changing the iris. Similarly as the eye moves to and fro, bright and dull objects successively affect the same portions of the retina to the disadvantage of the latter. For this reason reading rooms, workshops and similar places should have a good general light in addition to individual lights required in special places.

Illumination is greatly affected by the surroundings. A single lamp which satisfactorily lights a small room gives very poor light when in the open air. The principal reasons for this are two. In the open air there is practically no reflection of light from surrounding objects, while the walls and objects in a room increase the original light by reflection. Also, since in the open air the surroundings are dark, the eye must continually adjust itself as it wanders from the well-lighted area near the lamp to the dark areas beyond, and consequently tires more quickly than when working in a uniformly lighted space.

The walls of a room have a great effect upon the illumination produced. Each wall diffuses the light received and becomes a secondary source of light, a greater or less amount of which strikes other walls, where it again becomes a source of light. The result is that the original source of light is greatly reinforced. It is easily shown[55] that if the original amount of light be called Q, and the percentage reflected or diffused by the walls be called f, the total available amount of light is

$$Q\,(1 + f + f^2 + f^3 + \text{etc.}) = Q\,\frac{1}{1-f}\,.$$

The coefficient f varies from .004 for black velvet to 0.82 for white

[55] Palaz, "Industrial Photometry," pp. 298 and 318.

blotting paper, or perhaps .90 or 0.95 for polished glass mirrors. In the extreme case of a room with walls, ceiling and floor covered with polished mirrors having a reflecting power of 0.95, the total quantity of light would be about twenty times that of the original source. In a room with fresh white walls having a reflecting power of 0.80, the original light would be increased about five times. These figures are considerably reduced in practice by the presence of furniture, carpets, doors and other obstacles which intercept the light.

In artificial illumination, what is wanted is not so much candlepower as a certain intensity of illumination of the observed surfaces.

A light of the same candlepower will give greatly varying results, depending upon the distribution of the source, the character of the illuminated surfaces, whether polished or rough (*i. e.*, reflecting regularly or irregularly), the color, whether light or dark. The lighting contractor should, therefore, be required to produce a given degree of illumination rather than a given candlepower. This is beset with so many difficulties that he usually aims simply at so many candlepower. This is analogous to a contract for heating—not to furnish so much coal or so many B. T. U., but to maintain a certain temperature. In other words, the consumer wants to be warm or to be able to see plainly. In practice, it is difficult to guarantee the results for a reasonable contract price, since there are so many elements difficult to control, such as the opening of windows, or number and adjustment of curtains, the outside temperature and direction and force of wind. In heating the consumer takes upon himself most of the risk of such uncertainties and does not usually pay a fixed price, which would involve an ample margin to protect the supplyer. In a similar way, although not to so great an extent, the lighting of a house or other area has so many variables, the color and cleanliness of walls, ceilings and other reflecting surfaces, the cleanness and number or character of globes, shades and reflectors, that there are many matters of uncertainty. The time element also enters with a variable as to the changing length of day at different seasons, also the habits of the users of the room.

We may turn next to some discussion of illumination appearance as distinguished from illumination. For certain advertising and other purposes it is desirable to have the sources of light conspicuous, rather than objects illuminated by them. Familiar examples in Minneapolis are the tower lights on some of the corner stores, the incandescent crosses on the tower of one of the

churches, the rows of incandescent lamps along the cornices and windows of some of the stores, the headlights above the theatre entrances, and the numerous illuminated signs in which incandescent lamps form letters and words. The methods of obtaining the desired illumination appearance vary so widely, according to the effect sought, that we may not stop to consider them in detail.

Illumination combined with illumination appearance is desired in many cases. Here, again, the advertiser has developed excellent examples, such as the rows of arc lamps in front of the stores, which both attract attention from a distance and also light the store fronts and show windows. Fancy designs in the store windows also serve the double purpose, if the lights are not too brilliant, as when colored or frosted globes are used.

For lighting interiors of buildings, especially corridors and rooms with high ceilings, excellent effects may be produced, the arrangement of the lamps attracting attention while illuminating the area below.

The distinction between illumination and illumination appearance is not as well or as commonly known as it should be, and frequent blunders are the result. For instance, the ambitious country town insists on having its streets lighted by brilliant arc lights, in order thereby to attain a quasi metropolitan aspect. Arc lamps are indeed unexcelled for illumination appearance, and are therefore desirable for advertising the business streets of a town. They are excellent also for illuminating the streets, if placed not further than one or two blocks apart, and if twenty-five to thirty-five feet above the roadway. But with the not infrequent practice of hanging them eighteen or twenty feet above the roadway and long distances apart, the arcs serve as beacons to indicate the direction of the road to distant travelers and to blind those who are near. An equal amount of money spent in erecting and operating a much larger number of smaller lights, placed at shorter intervals, would far better serve the purpose of lighting the roadway and sidewalks with some uniformity, and of enabling persons to see the way clearly and safely. If beacons or lighthouses are wanted to indicate directions of streets, lamps of one candlepower placed one mile apart will serve the purpose equally well when no other lights are in sight. The ideal system of street lighting is to have arc lamps placed at short intervals in the business part of the town and to use smaller lights of twenty to fifty candlepower, and not further than one block apart in the residence districts.

BRADLEY & POATES, ENGR'S N.Y

WALTER WASHINGTON De LACY.

President Montana Society of Civil Engineers, 1892.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881

VOL XVIII. JUNE, 1897. NO. 6.

IN MEMORIAM.

Walter Washington de Lacy.

[Born February 22, 1819. Died May 13, 1892.]

Walter Washington de Lacy, the son of William and Eliza de Lacy, of Norfolk, Va., was born at Petersburg, Va., on February 22, 1819, while his parents were there on a visit, at the close of which they returned to Norfolk, where the son was brought up. His father died when the son was nine years old, and his mother when he was thirteen.

He was adopted by a bachelor uncle and two maiden aunts, who raised and educated him.

His paternal grandfather was a native of Wexford, Ireland, and a descendant of the celebrated Norman knight, Hugh de Lacy, who acted as first Norman Governor of Ireland under Henry II., in 1172. His maternal grandfather was an Englishman by the name of William Charles Lee, who for many years was English Vice-Consul at Oporto, Portugal, and in the West Indies. Lee was a man of great wealth at one time, but, being very profuse in his hospitality, he became impoverished. Whilst at Oporto he married a Portuguese lady who was a lineal descendant of the celebrated Portuguese general and explorer, Vasco de Gama, the first man who sailed the whole length of Africa and rounded the Cape of Good Hope in 1497, and conquered a part of India. Lee came to Norfolk about one hundred years ago. His house and large gardens are still there, inhabited by his descendants, cousins of Walter W. de Lacy, and at no time have they passed out of the family's possession.

Walter W. de Lacy commenced his education at home under the tutorage of his aunt, Mary, a remarkably well educated woman, and in 1834 was sent to Mount Saint Mary's Catholic College, near the town of Emmetsburg, in Maryland.

There he remained four years without returning home, progressing well in his studies, especially in mathematics and languages. He could speak French and Portuguese before he went to Emmetsburg, and, while there he learned to speak Spanish with great fluency, as there was a number of Spanish boys at the college from the West Indies and South America.

Whilst the boy was still at school, his uncle had been trying to get him an appointment at West Point, his claims being based upon his father's services in the War of 1812. Finally the uncle did receive an appointment for him, but a few days afterwards it was revoked on the alleged ground that the appointing clerk had made a mistake in names. The fact was afterwards ascertained that the mistake was not the clerk's, but that a nephew of General Scott was put in de Lacy's place, and thus his appointment was revoked, there being an identity of the initials of both names and a similarity in their spelling, the name of General Scott's nephew being W. W. Lacy.

Walter W. de Lacy returned home after his four years' study at college. As he began to think of making civil engineering his profession, his uncle wrote to Professor Mahan, at West Point, asking the latter's advice as to where it would be best to educate him for this profession. Professor Mahan answered that if de Lacy's uncle would send his nephew to West Point he himself would instruct the lad, privately and without charge. Professor Mahan was then in the zenith of his fame, and really the ruling spirit at West Point, regarded as being at the head of his profession in the United States.

The reasons for his kindness to young de Lacy were that he was indebted entirely for his position in life to William de Lacy's granduncle.

Young de Lacy went to West Point and boarded with the family of a retired officer named Kinsley, and recited to Professor Mahan every day in his class-room immediately after the section of cadets had finished. He also recited in the higher mathematics and in the use of instruments to Captain Bliss, who afterwards married the daughter of General Zach. Taylor, and was his Adjutant-General in the Mexican War. He studied topographical and mathematical drawing, besides, under Lieutenant Eastman, as-

sistant professor of drawing. While at West Point he associated with the cadets the same as though one of their number.

Walter W. de Lacy remained at West Point until he completed the course in mathematics, civil engineering and topography. At the end of that time he received an offer of a position on the Illinois Central Railroad, then in course of construction. He went to Baltimore, started by the Baltimore and Ohio Railroad and went as far as Frederick, thence by stage to Wheeling, thence down the Ohio and Mississippi Rivers to a place called Jonesboro. There he met a friend from his native town, Norfolk, Va., and was employed by him as rodman and leveller on the railroad for several months. This was in 1839. For some cause, probably from the lack of funds, the work stopped and the engineers were discharged. His friend and himself then went to Saint Louis and obtained positions on the Iron Mountain Railroad. Whilst engaged in this work he received an order from the War Department to present himself on a given date and stand examination for a commission in the regular army as a civilian. His friend told him he had better go to Washington, as the work on the railroad would soon stop. He returned home over the same route he had taken on his trip West.

At the appointed time Walter W. de Lacy went to Washington and found assembled about twenty civilians who had been ordered before the board. They had not been told what they would be examined in. The examination was very superficial. It consisted of a few questions, several sums in arithmetic, reading and writing a few lines from dictation, all of which he believed he answered satisfactorily. He did not show, however, as he ought to have done, his certificates from Professor Mahan and Colonel Bliss, and the topographical maps which he had made at school. Had he done so he probably would have taken better rank. As it was, he was offered the position of assistant professor in French, but he insisted on receiving a commission in the army before taking the appointment. He remained at West Point twelve months, when he was promoted to the rank of Captain, but he resigned and did not join his regiment.

A year later he was offered and accepted the appointment of professor of languages, French, Spanish and Portuguese, and acting professor of mathematics in the United States Navy. At that time the naval schools were on board the men-of-war. A greater portion of the following five years he spent at sea teaching midshipmen, during which time he served on the men-of-war Pennsylvania, Marion and Ohio, and visited most of the islands of the

West Indies and many points on the coasts of South America and Africa.

Upon the establishment of the United States Naval School at Annapolis, Md., he was tendered a professor's chair, but declined. A short time thereafter he was engaged in Government surveys along Lake Superior.

He was sent in 1846, by a party of capitalists, to Texas in search of old Spanish silver mines that had been abandoned.

Texas was at that time sparsely settled, and his exploration carried him to its furthest borders into regions where the red man held undisputed sway. He had as an escort a small band of Delaware Indians, who in intelligence and courage were nearly the equals of white men. Great danger attended the expedition. Several mines were discovered that had been worked for lead, but of gold or silver none. In pursuit of its object, the party crossed over into old Mexico, and were there when the United States declared war against that country.

Prompted by patriotism, Colonel de Lacy took part as a volunteer in several combats. After peace had been declared he joined a detachment of Texas rangers under command of Colonel Jack Hays, which was starting out for the purpose of locating a road from San Antonio to Chihuahua, Mexico. There were seventy men in the party. This expedition took them into a region comparatively unknown by white men. After being out for some time the guides confessed their ignorance of the route, and the command was brought to a stand-still. It was determined, however, to push forward. The commissariat was provisioned for twenty-five days, but for eighty days they wandered over the boundless prairies. The men were put on short rations, but finally the meager supply of food gave out and they were compelled to subsist on the flesh of their mules and horses. No game was to be found and they were frequently destitute of water for two days at a time. When almost discouraged, the command stumbled upon what was known as the old Comanche trail, and soon after this they reached San Carlos, the nearest Mexican settlement. On their arrival they obtained provisions and were kindly treated by the inhabitants.

The rangers then returned to San Antonio, but Colonel de Lacy, who had two pack mules loaded with merchandise, decided to remain. One day an Apache chief came into the settlement with whom de Lacy struck up an acquaintance. A mutual friendship was soon established between the two, and as a result the chief invited him to visit his country, which was in the Bolson de

Mapinii Mountains, the wildest and least known region in old Mexico. Always fond of romantic adventure, the Colonel accepted and spent several weeks with his savage host. Among other things of interest that he discovered while there was an Indian training school, where the boys were taught to imitate the howl of a wolf, the hoot of an owl, the cries of other animals and birds, and other features of Indian warfare. de Lacy was treated with great kindness and, finally, safely returned to San Carlos under an escort of Indian braves. Upon his departure his Indian friend presented him with a number of horses. To this acquaintance he subsequently owed his life.

Soon after he started with his mules and merchandise for Presidio del Norte, where a Mexican garrison was stationed. Two Mexicans accompanied him to drive the pack animals and act as guides. One evening the party was surprised by a band of ten or twelve Indians approaching on the charge, led by their chief, a huge savage. Few Indians in those regions possessed firearms, and the assailants had only bows, arrows and lances. The two Mexicans fled in terror into the adjacent thicket, leaving Colonel de Lacy alone. A moment later the chief raised his lance to strike a fatal blow. With steady nerve and quick eye, Colonel de Lacy turned in his saddle and discharged his rifle. The chief, with a loud yell, reeled in his saddle and fell dead. The following day the party arrived at its destination. The fame of this exploit quickly spread through the neighborhood and the Colonel became the hero of the hour.

He remained at Presidio del Norte for some time, soon becoming a favorite with the officers of the Seventh Mexican Infantry and the Chihuahua lancers, who were stationed there, and frequently taking part in their scouting expeditions. Becoming weary of life at the Presidio, Colonel de Lacy returned to San Antonio, and soon after joined a party of United States topographical engineers under Lieutenant Whiting, who were to undertake an expedition across the staked plains of Texas. The object of the expedition was to discover a feasible route for the Third United States Infantry, to locate places where water could be obtained and select sites for military posts along the Texas frontier and in New Mexico. The final destination of the expedition was El Paso. All for a time went well, but being in an unexplored country they missed the Pecos River, which was to have been a stopping place, and for five days wandered over the prairies without water. After the first forty-eight hours of the fearful experience, they remained in camp by day, travelling only at night.

Words cannot describe the suffering endured; the men became partially insane, and only through strict military discipline could Lieutenant Whiting control them. When they were almost hopeless and the last point of endurance was reached, on the night of the fifth day, the mules scented water and, thanks to the keen instinct of these animals, a fine stream of water was discovered. Both men and animals rushed into the water and appeased their fiery thirst.

Continuing its journey, the party reached the Rio Grande, where they one day met about three hundred Apaches who were about to massacre the expedition, but among the Indians were some of Colonel de Lacy's friends whom he had visited in the mountains of Mexico. Through their intercessions it was decided to hold a council on the day following and decide upon what action should be taken. The respite was utilized and the little party of thirteen silently withdrew during the night.

After visiting various points in New Mexico the party returned to San Antonio. Lieutenant Whiting afterwards became a general in the rebel army.

In 1850 Colonel de Lacy went to New Orleans to visit his relatives and friends. While there he was appointed hydrographic engineer to serve on a party that was to survey a railroad route across the Isthmus of Tehuantepec and establish seaports at each end of the proposed line. Seven months were occupied in making the survey. During a portion of the time the Colonel was detailed to visit the adjacent mountains for the purpose of gathering information regarding their mineral and other resources. To this end he travelled quite extensively in Mexico and learned much of its possibilities. The Colonel returned with his party to New Orleans, where it was disbanded.

For a period of three years after his Tehuantepec experiences, Colonel de Lacy was employed on the New Orleans and Jackson Railroad, where he met Benjamin H. Greene, also an engineer on that line, late member of our Montana Society of Civil Engineers, and also President of it at the time of his decease.

For a period of six months in the year 1854, Colonel de Lacy was engaged with a party in surveying the thirty-second parallel of latitude from San Antonio, Texas, to San Diego, Cal. At that time Arizona, or the Gadsden purchase, formed a part of Sonora, Mexico, though rumors of its purchase reached the explorers while they were crossing its deserts. The work completed, the Colonel proceeded to San Francisco, where he found his old friend, Jack Hayes, formerly of the Texas rangers, occupying the posi-

tion of Surveyor-General. Having made some surveys of Mohave River, de Lacy was sent to do similar work at Puget Sound in 1855. Soon afterwards occurred the Yakima Indian War. Two companies of volunteers were called for. The Colonel promptly responded to the call, and for three months his company was operating between Seattle and Steilacoon and had over a dozen combats with their enemies. On the arrival of Governor Stevens our Colonel was commissioned Adjutant of the Second Battalion, Washington Territory Volunteers. This cavalry command made frequent raids into the Indian country, captured many prisoners and hanged several. Peace with the tribes was declared in 1856.

Information being received that other tribes who had refused to make peace had a large camp in Grande Ronde Valley, the battalion was ordered to strike them. With Nez Perce guides, the command crossed the Blue Mountains and approached the enemy. As soon as discovered several hundred warriors rode out toward the soldiers, waving poles to which were attached the scalps of white men. The troops at once charged and a hot battle ensued. The savages were routed with a loss of eighty-five killed and six or seven hundred horses captured, besides abandoning a large part of their pack train, containing their winter supplies of camas. Five soldiers were killed and many wounded on both sides. Soon after the troopers returned with their captured horses and other trophies. While the battalion was camped upon the site of the present town of Walla Walla, for the purpose of effecting a treaty, Colonel Steptoe with two hundred regulars arrived, looking up a location for a military post. The Indians showing no disposition to treat, Governor Stevens, with his men, wagons, and wagon train, started for the Dalles. When he had gone some three miles distant from the camp the troops were attacked by the Indians in strong force, and were obliged to call on Colonel Steptoe for assistance. He promptly came to the rescue and the whole party returned to their original camping ground. Soon after the Indians disappeared and Governor Stevens and the volunteers returned to the Dalles. This completed the Colonel's active service in the war.

During the three following months Colonel de Lacy was engaged in making a trail from Whatcom to Thompson River. When the Frazier River excitement was on, his only companions were Indians, and when provisions gave out, for four days they subsisted on the bark of pine trees. Upon returning to Whatcom the Colonel found himself famous. During his absence the population had increased from six hundred to six thousand. He was

welcomed with a salute of one hundred guns and a public dinner. The mines proved a failure, and the glory of the expedition was all the compensation he ever received.

In May, 1859, he was attached to the command of Lieutenant Mullan, who was organizing an expedition into Montana. After making surveys of Columbia and Snake Rivers he joined the command at Cœur d'Alene Mission. The party went into winter quarters on the St. Regis Borgia. The spring following the eastward march was resumed, and he was required to make surveys that might be utilized should a railroad ever be built along the route. In performing this work he one day lost his way and made a solitary bivouac in Last Chance Gulch, where now stands the City of Helena. The expedition on arriving at Fort Benton met four hundred troops en route to the Pacific coast. de Lacy returned to Fort Walla Walla, where he was discharged in 1860.

In company with three others, in 1861, he was prospecting in Montana. They met with no very great success. In 1862 he outfitted a pack train at Walla Walla and came to Gold Creek, Montana, and from there went to Bannack, spending the following winter at Fort Owen.

In 1863 he organized an expedition to explore South Snake River. The party travelled up to the head of that stream, thence through Jackson's Park, and discovered Shoshone Lake. This beautiful sheet of water was very properly named de Lacy, and the honor was confirmed by Surveyer-General Meredith, but Professor Hayden some years later changed the name to Shoshone. After passing through Fire Hole basin the party returned to Virginia City.

In 1864 Colonel de Lacy laid out the town site of Fort Benton, after which he returned to Bannack in time to be present at the first meeting of the Territorial Legislature, and by its orders made the first map of Montana. In 1865 he laid out the town sites of Deer Lodge and Argenta, in Montana. In 1867 the Sioux war occurred and he was appointed Colonel of Engineers by Governor Meagher, and took charge of a supply train for the relief of Fort C. F. Smith.

The undertaking was very hazardous, but they arrived safely. After this he and Professor B. F. March located the initial point for public surveys in Montana, and ran the principal base-line. For the next three years he occupied a position in the Surveyor-General's office, during which time he made a map for the Northern Pacific Railroad Company and furnished them some very valuable information.

In 1871 he made a survey of Smith River Valley, and in 1872 surveyed the Salmon River for the Union Pacific Railroad Company. After that year Colonel de Lacy followed the practice of his profession. He was elected City Engineer of Helena in 1883 and re-elected in 1884. Soon after, in 1886, his friends strongly urged the appointment of Colonel de Lacy to the office of United States Surveyor-General for Montana, but Colonel B. H. Greene was appointed to the office and assumed his duties in the latter part of that year. He appointed Colonel de Lacy Chief Mineral Clerk, and afterwards Chief Clerk of the United States Surveyor-General's office in Helena, Montana, and the Colonel filled a position in this office up to the time of his death. Colonel de Lacy and General Greene were, in 1852, both engineers upon the New Orleans and Jackson Railroad, and were frequently together, but after that they did not meet until in December, 1885, when General Greene arrived in Helena. Their old friendship was soon renewed. General Greene frequently spoke of Colonel de Lacy in the highest terms as a most remarkable man. Both General Greene and Colonel de Lacy were charter members of the Montana Society of Civil Engineers.

Two years after the decease of B. H. Greene, at the time President of our Society, the memorialist is again called upon to record the death of another of our honorable Presidents. Most of our members recollect Colonel de Lacy as a very old man, of very remarkable memory, well posted upon nearly every subject that was brought up in conversation; familiar with all parts of this Western country; very interesting to listen to in his accounts of adventure and hardships, and with a very pleasant and entertaining way of expressing himself. He was very well known and highly respected in the West.

He was an incorporator of the Montana Historical Society, and was President for one term of the Society of Montana Pioneers, a well deserved honor, as his first experiences in Montana occurred long before those of any other of the members of the Pioneer Society. He was very generous, having contributed considerable sums to several benevolent institutions, as well as assisted some of his relatives in the South. For several months before his death his health became impaired, and it was apparent that age had overcome his healthy constitution.

At one o'clock on the morning of May 13, 1892, he passed away. The only relative Colonel de Lacy had in Montana was a cousin, William de Lacy, a well-known citizen of Helena. Distant relatives still live at his old home at Norfolk, Va. His two

maiden aunts, Mary and Alicia de Lacy, to whom he was so much indebted for his early care and education, died there in November, 1862, of yellow fever, which was then raging with fearful mortality. His uncle died at New Orleans during the Civil War.

PAINT TESTS.

By Max Toltz, Member of the Civil Engineers' Society of St. Paul.

[Read before the Society, December 7, 1896.*]

This paper records the result of considerable thought, study and time, which have been given to the above subject during the last three years in making careful laboratory examinations of the various paints sold in the markets as "anti-rust," and under other names, and in practical experiments.

The compilation of the work thus far done is given in a condensed form only; therefore, the usual style of reporting is reversed, and the recommendations and conclusions arrived at are given at the beginning.

From our present knowledge, the following system for painting iron and steel bridges and other metallic structures is recommended:

First. Give the iron and steel a coat of the best grade of refined linseed oil, properly boiled and settled clear; or, still better, mix linseed oil with about 10 per cent. of a good grade of lampblack; this coat to be applied at the mills, the iron or steel being first carefully cleaned from loose scales.

Second. After the structures have been erected, give them one coat of real asphaltic varnish paint, made from the best grade of asphalt, linseed oil and gum, compounded properly, so as to form a true varnish; or of a paint made from carbon black and a properly boiled varnish, compounded of the best grade of linseed oil and gum. This coat should be carefully applied by a skillful painter, after the metal has been thoroughly cleaned from all loose scale, rust, shavings, filings, shrivelled oil or paint, grease, dirt, or any foreign matter, because it is of the utmost importance that the paint should be spread and worked in such a way so as to cover the surface properly, and be as free as possible from air bubbles and form a continuous coating. This priming or first coat should be applied fairly thick, the thickness depending, to some extent, on the nature of the paint used. Before the second coat is applied, the first one should be thoroughly dried and hardened by natural oxidation, which will require at least ten days. If practicable, it would be a great deal better, as well as more economical, to apply the second coat not less than four weeks after the first one.

*Manuscript received May 24, 1897.—Secretary, Ass'n of Eng. Socs.

Third. As a second coat, a good grade of graphite paint is to be applied as thickly as possible, working the paint thoroughly with the brush. From the examinations made of the various grades of graphite paints, as far as graphitic pigments are concerned, there appears to be but little difference between them, provided, of course, that the pigment contains at least 33 per cent. of pure graphite, the rest of the pigment being natural rock, ground very fine in pure linseed oil. The graphite paint should be bought in paste form, well ground, and contain not less than 70 per cent. of pigment and 30 per cent., by weight, of the best quality of boiled linseed oil; the paste should be mixed with boiled linseed oil at the place where it is to be applied. No turpentine, no benzine, and no Japan or driers should, under any circumstances, be allowed in this paint.

The system just described, if properly carried out, will give a protective coating which will last for many years, and it is firmly believed that this system of painting (provided that the paints are of the best quality) will protect iron and steel for a longer period than any other system now in vogue.

Fourth. There are certain parts of steel or iron bridges, viaducts or tunnels that should have an additional (third) coat of paint. These include such places, or parts of structures, as are directly exposed to the steam, fumes and gases from passing engines. For such a coat some cheaper asphalt paints, applied very thickly over the coats above recommended, would be all-sufficient. Such a coat would protect the underlying primary coats for many years, preserving their natural toughness and elasticity, and preventing atmospheric action on the structure.

In the past, red lead was largely, if not exclusively, used as a paint for iron and steel structures, but within the last ten years it has been to a great extent discarded by progressive engineers and builders. It is true that we to-day have advocates of red lead as the best paint. Still, the fact that these so-called red-lead men now begin to add carbon black or graphite to their paint, is a sure sign that they themselves no longer believe red lead alone to be the best pigment.

Fifteen years or more ago iron-oxide men appeared and flooded the country with their various grades and qualities of iron-oxide paint, as being the paint which nature itself had provided for the protection of steel and iron structures against rust and corrosion. From the investigations made, as well as from practical experiments, it appears that the iron-oxide paints are not very desirable, at least for the first coat or two, for iron or steel; but,

as a third coat, for the protection of the underlying paints, they may be recommended.

However, the extensive investigation of the graphite paints that can be obtained in the markets to-day shows that, if properly applied, they are far superior to iron-oxide paints for the second or third coat, especially as they withstand the action of moisture and water much better than the best iron-oxide paint so far examined. Besides, a graphite paint, in paste form, well ground and mixed with boiled linseed oil, will not cost very much more per gallon than the cheapest iron-oxide paint in the market.

In recommending asphalt varnish paint or carbon paint for the first coat, great stress is laid upon the necessity of having the surfaces of iron or steel as free from moisture as possible while the structures are being painted, otherwise there is great danger that the coating will not adhere very firmly, and that it will thus actually nullify the value of the paint. This precaution is less important when an ordinary iron-oxide paint or red-lead paint, simply mixed with linseed oil, is used; because linseed oil itself has the property of absorbing moisture quite readily, whereas carbon or asphalt paint will not. The lack of this property in the two last-named paints is one of the principal reasons why they are superior to any other class of paints.

Although it is proper that true economy should always be exercised, preference should not be given to any paints whose properties lie simply in the fact that small quantities of them cover great areas. Often the first question asked is: "How many square feet can you cover with a gallon of your paint?" cheapness being considered the most important factor. Of course, the greater the number of feet that can be covered with one gallon of paint the thinner will be the protecting coat. There is a limit beyond which it is inadvisable to carry this. Other things being equal, the paint that can be spread over a fairly good area should be considered superior to any which goes to the extreme either way.

The various paints examined are classified under the following heads:

First. True asphaltic varnish paints.

Second. So-called asphaltic varnishes or paints, of inferior qualities.

Third. Black carbon paints, in which the vehicle is practically a varnish.

Fourth. Iron-oxide paints, consisting of more or less iron-oxide with more or less siliceous matter and compounds of lime or of magnesia.

Fifth. Graphite paints and silica graphite paints.

The tests were carried on through periods ranging from six months to over two years. The number of paints subjected to test was twenty-two. All these paints have been analyzed chemically to ascertain the quality of material used in them.

The true asphaltic varnish paints are compounded in the same manner as the black japans, known as baking japans, and are made practically in the same way as varnishes, from linseed oil, gum, asphaltum and turpentine. Some of them contain carbon black and a small amount of inert mineral matter.

The carbon paints consist, as regards the pigment, mostly of carbon black, with some white lead; the vehicle in which the paint is ground is practically a linseed oil varnish, thinned down with turpentine. These two paints are closely related to one another and are comparable. Both are considered to be of great value for the protection of iron and steel, if properly applied.

The asphalt paints of inferior quality, which might be of value as a last coat, or wearing coat, especially on certain parts of bridges, viaducts or tunnels are made of asphaltum dissolved in benzine or other volatile oils, but are not a true varnish made from linseed oil. They contain about 43 per cent. of volatile oils and 56.5 per cent. of solid carbonaceous bitumen (asphaltum).

In using these paints, namely, asphalt dissolved in benzine, in mixtures of benzine or rosin spirit, or in other light neutral oils, the principal trouble is that in spreading them over oiled surfaces the light oil evaporates so fast that it is difficult to spread them properly. There is also another objectionable feature in connnection with the benzine paint, namely, that where such a paint is applied to iron surfaces the rapid evaporation of the benzine absorbs a great deal of heat, and, if the air should happen to be highly saturated with moisture at the time, the reduction in the temperature of the surface of the adjacent iron may cause a condensation of moisture, preventing the paint from coming in close contact with the iron and producing a tendency to blister.

These cheap asphaltic paints may show up well enough in the beginning, but as a rule, after the volatile oil has evaporated, especially in subjecting the painted iron to the heat test, the coats become quite brittle, can be easily removed by abrasion and do not protect the iron against rust.

As a matter of interest, it may be stated here that one of the so-called asphaltic paints when analyzed chemically showed no asphaltum at all.

The iron-oxide paints were of different grades and qualities.

It is not the intention of the writer to give their chemical analysis, because every paint was compounded differently and contained more or less iron oxide and siliceous matter. As a rule the paints were well ground, and spread and covered to a satisfactory extent.

As stated before, the graphite paints contain from 33 to 83 per cent. graphite, the balance being inert insoluble matter, consisting mostly of compounds of lime, magnesia, alumina and iron oxide.

Besides the chemical examination, the paints were subjected to a systematic practical test, to ascertain their real values as anti-rust paints. For that purpose comparative tests, by painting pieces of sheet iron, tinned iron and galvanized iron, wooden boards and shallow sheet iron dishes, were carried on. The iron dishes were about 12 inches in diameter and about $\frac{1}{2}$ inch deep, having a capacity of about $\frac{1}{2}$ pint. The scale or skin was carefully removed before painting, so as to have a clean surface of iron exposed next to the paint. Two dishes were painted with each kind of paint—one of them receiving one coat, the other two coats, the first coat having dried thoroughly (for at least a week) before the second coat was applied. After the second coat had completely dried and hardened, these dishes were exposed to the so-called water-and-moisture test, in which a given amount of water is placed in the dishes and allowed to evaporate to dryness at the ordinary temperature of the room. This is repeated a number of times, until the inside of the dishes begins to show more or less rust. All dishes were carefully examined before each refilling. After most of the water has evaporated, there remains, at the junction around the edge, a thin film of water, which, in contact with the air and with the carbonic and other acids in the air, acts on the paint in such a way that the iron under the paint begins to rust. The rust thus formed develops more and more after each evaporation, in some cases practically covering the whole dish in a short period. In actual practice and service, the same thing will happen, the only difference being that the rust will extend under the paint and will not show as plainly as on the dish. This test is a most important and severe one for the purpose of determining in a relatively short time the weather-resisting power of a paint. If the paint is unable to resist this action of the water or moisture under these conditions, it cannot be desirable for the protection of iron or steel structures. But other qualities in the paint have to be taken into consideration in connection with this test before a correct opinion as to its merits can be formed.

The dishes painted with true asphalt varnish and with the carbon paint were refilled fourteen times. The dishes painted

with one coat showed very little deterioration, while the dishes with two coats showed none at all, the paint being as elastic and tough as when first applied.

The behavior of the cheap and inferior so-called asphalt paints, applied on the surfaces of the dishes, was quite different. After the fifth exposure, the dishes with one coat showed considerable rust all over. Those with two coats, after the seventh exposure, showed not much better.

Quite a difference was apparent in the test of the iron-oxide paints. On the average, after the fifth exposure, a good many rust spots or specks appeared on the surfaces of the dishes painted with one coat. The dishes with two coats were refilled six times and on them rust could be easily detected with the naked eye.

The graphite paints so far examined acted much the same in comparison with one another; although, upon chemical examination of the samples submitted, quite a variation was found in the amount of graphite present in the pigment.

The object of procuring the graphite in the form of paste was, in the first place, to get the paints ground only in boiled oil, so that they could be thinned with oil before painting, under exactly the same conditions; second, if, after the examinations and tests, any difference was found, it would be easy to ascertain whether or not such difference was due to the amount of graphite present. In mixing these different graphite paints with boiled linseed oil, ready to apply, $4\frac{1}{2}$ parts of paint and $3\frac{1}{2}$ parts of oil, by weight, were used. As all these graphite paints were received at about the same time, all the comparative tests were made under exactly the same conditions, and all moisture or water tests were made side by side. Therefore, the results obtained so far are comparative and consequently of more value than otherwise would have been the case. All the dishes with one coat were exposed ten times to the water test, and on examining the records it will be observed that all these graphite paints began to show a few specks of rust after the fifth evaporation, and that the number gradually increased after each successive evaporation. After the tenth exposure some slight difference between them is shown, but not very much. All the dishes given two coats have so far been exposed thirteen times, and none of them show any rust or indication of rust. The natural toughness and elasticity is still in the paint after the treatment.

Besides this moisture-and-water test, all paints have been subjected to a heat test, by placing painted sheet iron in the core oven of the brass foundry of the Great Northern Railway shops. The temperature of this oven varies from 220° to 300° Fahrenheit, and,

as the fire is a direct one, all the gases of combustion, such as carbonic acid, sulphurous acid, and watery vapor, came in direct contact with the painted iron. This test is of value also as showing promptly whether a paint will keep its elasticity or will become brittle so that it may be easily removed from the surface. In several instances this test brought out serious defects in some of the paints examined, which had shown fairly good results in the other tests. This was the case especially with the cheaper so-called asphalt paints.

After a month's exposure to the heat of this core oven, the painted pieces of sheet iron were examined, and the asphaltic varnishes, carbon paints and graphite paints only were then found in good condition, although the paint had become very hard, owing to the thorough oxidation and hardening of the linseed oil. These three paints adhere very firmly to the iron after the heat treatment; in fact, they seem to be more strongly attached to it than to a painted surface not exposed to heat.

The exposure of the painted iron to this high temperature is not exactly the same condition to which it will be subjected in actual service; but this test, in connection with the others, is of value, because if the paint should become very brittle or should flake off and be easily removed from the painted surface during this test, it will surely do so in practice after a long exposure to the direct action of the sun, and to great variations in temperature.

The writer wishes to give due credit to Dr. P. H. Conradson, who very skillfully carried out these tests when at the head of the Great Northern Laboratory.

DISCUSSION.

Mr. C. F. Loweth.—The author very properly reiterates the necessity for the exercise of care and intelligence in the application of paint to metal surfaces; almost any kind of paint will answer if it is to be but indifferently applied.

The application of a priming coat of high-grade oil, as soon as practicable after the metal is rolled, is undoubtedly good practice. There are, however, special paints which are best applied to the natural surface of the metal.

The exposure of the structure may to some extent determine the expensiveness of the paint to be used; if the exposure is only to wind and weather less is required of the protective coating than on train-shed or shop roofs, or on bridges over railroads. We had recently to take down a street bridge which spanned several much-used railroad tracks. The bridge had a wide, tight floor, which

held the smoke from passing locomotives in contact with the structure for a long time. The bridge had been put up but about six years, and had not been painted since its erection, the paint at that time being probably of a very common grade. All of the metal-work under the floor was very badly rusted, and the surfaces in contact at the lower chord panel points were by far in the worst condition. For all such cases the best quality of paint, and its most thorough application, especially to surfaces in contact, are very desirable.

I cannot agree with the author that "iron-oxide paints are not very desirable." Where honestly made, they have, even under severe conditions, given very general satisfaction. The qualification is important, as oxide, carbon, or asphalt paints may be alike good, bad or indifferent, depending on the purity of the ingredients and the thoroughness of manufacture.

A graphite paint is a carbon paint, as graphite is a form of carbon. It is not a new product, as the Dixon Crucible Company has been making such a paint for about twenty-five years. A graphite (?) paint with but 33 per cent. of graphite can be called a graphite paint only by courtesy, and may be good or otherwise, depending on the character of the remaining 67 per cent. of the pigment. If this is largely silica it will doubtless be a good paint, but it should be called a silica or silica-graphite paint.

The black paints used for street signs are doubtless largely carbon made of lamp or boneblacks. On old, weather-beaten signs it is frequently the case that the black paints remain in good condition, while the surfaces, originally painted white, and probably with oxide of lead, have become nearly or quite exposed.

The test by exposing the samples in a core furnace seems unnecessarily severe. A paint thoroughly suitable for metal surfaces exposed to ordinary conditions of weather might not show up well in this furnace test. A paint suitable for metal surfaces of high temperature must be a specially prepared paint.

Mr. A. Munster.—I think we are all greatly indebted to Mr. Toltz for his experiments on the qualities of paints for iron work, and for his discussion of the information thus obtained.

It is a very serious problem for all structural engineers, and especially so for us here in St. Paul, where we have not less than twenty-four iron bridges spanning railroad tracks and exposed to the steam and fumes from locomotives.

The protection given by the common iron-oxide and lead paints to the part of the iron-work directly exposed to the smoke, is of such short duration that it seems hardly worth while to put

them on; and we have from time to time used different kinds of so-called asphalt paint with no better results.

In 1895 we used, for the first time, an asphaltum varnish on our Sixth Street viaduct. The following year the same class of paint was used on the new Como Avenue bridge and the Mississippi Street bridge. The varnish did not show very enduring qualities on that part of the Sixth Street bridge across the tracks of the Great Northern Railway, where the traffic is very heavy, but the weather was getting cold while the painting of this bridge was in progress. The varnish, in consequence, became very thick and difficult to spread, and I have a strong suspicion that, in spite of all watchfulness, the painters added benzine in order to thin it, an addition which, the manufacturers claimed, would be distinctly injurious to the varnish.

Last year we painted eight of our bridges, and, for the sake of getting a comparison of their qualities, we used the following kinds of paint: Graphite paint, an anti-rust paint (with a priming coat of red lead), asphaltum varnish and asphaltum paint (asphalt dissolved in benzine).

In the panels of the Sixth Street viaduct, already mentioned, from which the asphaltum varnish had peeled, we painted sections with each of these paints, so that they should be exposed to the same conditions.

Inspection of the bridges during last spring shows a decided difference in the quality of the paints. The anti-rust and asphaltum paint had failed entirely wherever exposed directly to the smoke from the locomotives—(although in fairly good condition on the other parts of the bridge)—while the asphaltum varnish and the graphite are apparently in the same condition as when first applied, and further exposure is necessary to determine the relative values of these two paints. The graphite paint has one initial advantage over the asphaltum varnish, in that it can be used under all ordinary conditions of temperature, while warm weather is necessary for all painting with the varnish.

Mr. K. E. Hilgard.—I cannot agree with the statement that the addition of carbon (lampblack), graphite, white lead, Japan drier, or turpentine, to red lead should be made on the grounds of dis-belief in the protective qualities of red-lead paint. The thorough mixing of real red lead with genuine and actual fire-boiled linseed oil is not an easy matter, unless a special mixer is available, and, owing to running, it is usually difficult to spread the mixture uniformly. To overcome this, an admixture of the above-named additional pigments and thinners is frequently resorted to,

for one reason. Another still weightier reason, however, for such admixture is the desirability of obtaining a color sufficiently different to clearly distinguish each successive coat of paint. This is a quite important feature, from the standpoint of the bridge engineer, and from that of his inspector in particular, inasmuch as it is not easy to obtain two actually "all-covering" coats of the same paint and color. The great desirability, correctly pointed out, of allowing one coat to dry thoroughly, on the surface at least, before the next is applied, suggests naturally that the painting be done by the railway company's own men, kept in rotation between several structures, instead of by contract. Quite satisfactory results in painting structures on the Northern Pacific Railway system have been obtained within the last few years by using genuine red-lead paint or genuine black asphaltum varnish for a first coat to protect the metal, and following this in turn by one or more successive "overcoats" of dense linseed oil paints, in which the finely ground pigments were either iron oxide, graphite or similar substances, such as "Bessemer," "Silica Graphite," etc.

I fully agree that the area covered with one paint and used by one gang of painters on a certain class of structures, and under certain atmospheric conditions, in a certain season and certain locality, is no just criterion for comparison with the area covered with another paint on another class of structures, applied by a different gang of painters in another season, and under other conditions (referring to work being done either by "contract" or "company's force account"). In my opinion the covering capacity, which is usually the principal argument made by paint agents, is one of the most valueless which they can make, inasmuch as the actual area covered with the same paint is considerably influenced by the personal equation of the user and by other circumstances just mentioned. The most desirable and effective protective coat for a clean metal surface of steel or iron structures is a heavy coat which does not dry too quickly on the metal surfaces, which will assume a hard though not brittle outer surface, and which will not flow under the effect of heat; and I find this can be obtained by a heavy coat (applied after erection) of red lead or genuine black asphaltum varnish, both of which show great adhesion and elasticity, and can be made to remain in that condition for a considerable length of time is well protected by effective "overcoats" as just suggested. Any paints containing benzine, kerosene, tar, rosin, spirits or other volatile oils, small quantities of turpentine alone excepted, are believed to be of little or no value for protective coats.

The admixture of carbon or lampblack with the oil, if applied on the structural material previously cleaned from scales, rust, grease and dirt, at the shop, or preferably at the mill, is not believed to be of great importance, inasmuch as the principal advantage of this priming coat of oil, next to preventing early rusting, is that within a week or ten days, or sometimes even sooner, it tends to loosen scales which, previous to oiling, could not be removed by scrapers. It thus permits their subsequent removal. The oiling seems to affect the scales in the same way as (to some extent) it affects rivets. It has been observed that rivets, found absolutely tight after cooling, have been slightly, although seldom "objectionably," loose within a week after the material had been oiled.

No mention has been made regarding the sand-blast action of steam escaping through locomotive smoke-stacks, "blowing" while standing under bridges with little head room. Such bridges are frequently found at terminals. I believe that this injurious action could to some extent be effectively counteracted by applying an additional heavy coat of red-lead paint, or better, real asphaltum varnish, sanded over with sharp, clean, hard sand by means of an air-blower. This has been frequently suggested, but no occasion has offered itself for its trial within the scope of my jurisdiction. A heavy coat of paint which does not dry too quickly on the metal surface will at the same time better protect the metal itself from becoming very hot under the effect of the sun's rays and the injurious effect of expansion and contraction on the protective coating is in turn diminished. While many of the results obtained and deductions made from Dr. Conradson's most intelligently and carefully made laboratory tests, and so interestingly presented to us by Mr. Toltz, are very valuable, it is not believed that all of these tests alone can form an absolute substitute for observations or experiments with different paints made on the actual bridge structure, with due consideration of the different circumstances and conditions under which the paint is applied, and to which the structure itself is subjected.

Few shops are equipped with sufficient room under cover for storing material which has been received from the mills, although this is very desirable. At some shops visited by me, iron or steel that is not worked up at once in the shop is allowed to rust to a most objectionable degree. Of course, it is supposed and claimed to be cleaned again before painting, but I have observed cases in which, if this were done properly, the manufacturer would find it cheaper to acquire covered storage space. I can concur to only

a limited degree in the opinion of some shop men that slight rusting of iron and steel previous to the application of the first coat of paint is not only harmless, but even desirable, because the paint will adhere more firmly. The only slight advantage gained from incipient rust is the loosening of scales, but, as already pointed out, this advantage can be gained in a much greater measure by oiling the material previous to its receipt at the shop. In my experience, it has been found that it is quite satisfactory to defer all actual painting until after the structure is erected, except such surfaces as are not accessible thereafter. It is found that a good "old-time" coat of real kettle and fire-boiled linseed oil will sufficiently protect the iron-work from four to six months where it is not exposed to particularly unfavorable atmospheric or other influences. This practice has thus permitted us to defer the painting to the season most suited for that work.

It is especially important that red-lead paint, and even more so that asphaltum varnish, be applied at a favorable season.

ON THE ORIGIN OF THE CHÉZY FORMULA.

$$v = c\sqrt{rs}.$$

By Clemens Herschel, Member of the Boston Society of Civil Engineers.

[Read before the Society May 19, 1897.*]

The place where the Chézy formula was first stated has long been sought for. So careful a student as Hagen, in his "Researches upon the Uniform Flow of Water," in 1876, says, p. 65, that Prony states that Chézy set up this formula in 1775, on the occasion of a report that Chézy made on the Canal de l'Yvette in conjunction with Perronet. "But," says Hagen, "I have sought in vain for further information on the subject."

Through the kindness of a friend in Paris, I have traced the original Canal de l'Yvette report to its hiding-place, and the following is a translation of so much of that report as refers to the formula in question. To the best of my knowledge and belief it is now for the first time printed.

When we have a flow of water to convey, either to procure some at a place where there is none, or to drain a territory which has too much of it, we should always cause a maximum quantity to flow with the least possible slope.

After having designed a ditch or channel, and having adjusted and regulated its slope, it is very interesting to know if the section of this channel will be sufficient to conduct the water which is to flow in it. To know this, it is necessary to know the speed which the water will have in the ditch, which we will suppose to have a uniform slope.

This is not now a question of initial or momentary velocity, which may be very great if it is caused by a head of water, or very little at first, if it is caused by no other force than that of gravity and the slope of the ditch. Whatever be the initial velocity, it will diminish or augment quite rapidly, and will become that uniform and constant velocity which is due to the slope of the ditch and to gravity, whose effect is impaired by the resistance of friction against the sides of the ditch.

It is this velocity which we are now to learn, at least approximately. The question thus proposed presents its own solution, for it is evident that the velocity due to gravity alone, which acts con-

* Manuscript received June 7, 1897.—Secretary, Ass'n of Eng. Socs.

tinuously (abstracted from the velocity which may have come from any other cause, and which, being soon dissipated, no longer concerns the question), this velocity due to gravity is only uniform when it is no longer accelerated, and gravity does not cease to be accelerated, except when its action upon the water is equal to the resistance occasioned by the wetted perimeter of the ditch, but its resistance is as the square of the velocity, on account of the number and force of the particles moving in a given time; it is also as the length of the wetted perimeter of the ditch. The resistance of the air against the surface of the water may be neglected.

If we call V velocity, and the wetted perimeter P, the resistance of friction will therefore be as VVP.

On the other hand, the effect of gravity is as the area of the section of the flowing water and as the slope of the ditch, or as the height which it falls for each toise (6.4 feet) of length.

Calling now the area of the section a, and the slope of the ditch h, the effect of the gravity will be as ah.

This granted, if by a good observation one knew the slope of
a ditch.................................... H
the area of the section of the flowing water......... A
its velocity.............................. V
and the part of the perimeter of the section of the flowing water touching the confines of the ditch.. P
it would be easy to find the velocity............... v
of the flowing water of another ditch of which one would know the slope....................... h
the area of the section......................... a
and the quoted portion of the perimeter........... p
for one would have the proportion

$$V\,V\,P : A\,H : : v\,v\,p : a\,h$$

whence, ...$V\,V\,P \,.\, a\,h = v\,v\,p \,.\, A\,H$

and

$$v = V \cdot \sqrt{\frac{a\,h\,P}{A\,H\,p}}\ *$$

It is easy to see, that to make use of this formula, it is necessary to have an experiment in which all the data are known.

*Note.—Some persons, even those versed in the science of mechanics, have said that the velocity of currents was approximately as the square root of their fall, and knowing that the velocity incurred by a body falling, whether freely or along an inclined plane, was as the square root of the height of fall, have believed, without giving the matter further attention, that the velocities of currents of different slopes were in the same proportion from the same cause. It is easy to see that this is an error.

It has seemed to me proper to report two such in this place, which were made with all the care of which I am capable.

Desiring to know what slope it was proper to give to a ditch, at the time I was at work on the Canal de l'Yvette, I took a trip into the forest d'Orleans, to measure the slope of the Courpalet Canal, which furnishes the water to the summit level of the Canal d'Orleans, knowing that it had very little slope in proportion to its length. I found by a line of levels, run twice very exactly, that the slope of this feeder, on the 23d September, 1769, was 3 feet 5 inches, 2 lignes (3.657 feet) upon its total length, which is 16,100 toises (102,953 feet).

The summit level of the canal was then very full, the water-level being only 10 inches, 11¼ lignes lower than the top of the side-wall of the main basin on the Grignon side, near the stop-plank groove, down stream from the side of the feeder.

The inequalities in the bed of the feeder and various obstructions, which made the total fall unequally distributed, prevented me from measuring it; I confined myself to making the following experiment on a portion which seemed to me most fit to give what I desired.

FIRST EXPERIMENT.

To know the velocity corresponding to the slope, I chose a portion of the feeder as straight and as uniform as possible, at a place called la Gibonnière, on a calm day.

A ball of wax thrown into the middle of the feeder passed over 101 toises in 23 minutes, and the second time, 99 toises in 22 minutes and a half; that is, approximately, 5 toises, 3¼ lignes per second (0.468 feet per second).

The slope of the ditch in this portion, levelled several times, was found to be 6¼ lignes per 100 toises of length (0.07224 per 1000 feet).

The sides of the ditch at this place are lined with plank, resting against small uprights, held apart by bracing. These uprights, presumably, retard the velocity a little; the feeder, otherwise in quite good condition, very straight and quite uniform on a considerable length above and below the point of observation.

The mean width between the uprights was 4 feet 0 inches, $\frac{2}{3}$ lignes (4.269 feet), and the mean depth of the water was 1 foot 7 inches, 2 lignes (1.702 feet); consequently the volume which flowed was 421 water inches (3.4 cub. ft. per sec.).

According to this observation, we have:

V = 5 inches, $3\frac{1}{4}$ lignes (0.468 ft.)
H = 0.0625 (0.07224 per 1000).
A = 6 feet 4 inches, 9 lignes (7.265 sq. ft.)
P = 7 feet 2 inches, 4.666 lignes (7.679 ft.)

SECOND EXPERIMENT.

The Seine, levelled on the 7th of October, 1769, with all possible care, had 11 inches (0.967 ft.) fall in 1330 toises (8505.4 ft.) of length, from the Surenne Ferry to the new bridge at Neuilly. It ran through this space in 55 minutes, the height of the water being 4 feet 7 inches, 6 lignes above low-water mark.

The branch of the Seine where this experiment was made is 50 toises in mean width, and had then about 9 feet depth of water.

The velocity of the water was, therefore, 2 feet 5 inches per second (2.576 ft.), and its slope was 1-10 of a ligne per toise (that is, 0.1157 per 1000 ft.)

According to this experiment, we have:

V = 2 feet 5 inches (2.576 ft. English measure).
H = 0 feet 0 inches, 0.1 ligne (0.1157 per 1000).
A = 2700 feet 0 inches, 0 lignes (3066 sq. ft.)
P = 318 feet 0 inches, 0 lignes (338,988 ft.) *

*NOTE.—If, from the experiment at la Gibonniere, it were attempted to compute the velocity of the Seine, from Surenne to Neuilly, one would find:

$$\frac{P\,a\,h}{p\,A\,H} = 15.291 \text{ lignes}$$

$$\sqrt{\frac{P\,a\,h}{p\,A\,H}} = 3.9 \text{ lignes}$$

$$V\sqrt{\frac{p\,a\,h}{P\,A\,H}} = 246.675 \text{ lignes} = 20 \text{ inches, } 6\tfrac{2}{3} \text{ lig.}$$

instead of 29 inches, as found by the experiment.

This difference properly comes from the fact that la Gibonnière was much retarded by the little uprights; and perhaps other elements, such as the tenacity of the water, ought to enter into the question also. Besides, the conditions of these two experiments were so different that one should not expect to conclude from one to the other, and it is remarkable that the results of the formula do not differ more from those of the experiment than above stated.

To derive a possible advantage from this theory, it is necessary to have a great number of observations upon channels of different sections. It would be necessary to use these observations which most resembled the projected channel.

It would be interesting, also, to have similar observations upon different brooks and rivers; but it is important to remember that all these experiments demand the greatest care; that it is very difficult to make them with sufficient precision, and that one ought not to rely upon any except those made by persons known to give them the most scrupulous attention.

For the present, and by means of the preceding formula, we are enabled to compute the velocity of the water in a projected channel, such as the Canal de l'Yvette, from either one of the two observations above given.

We suppose that it may have 5 feet width at the bottom, 6 at the top, and 5 feet of depth, that it is full of water, and that its slope is 18 lignes per 100 toises. We shall then have:

h = 0.18 lignes (0.2083 ft. per 1000 ft.)
a = 27 feet 6 inches (31.24 sq. ft.)
p = 15 feet (15.99 ft.)

and in making use of the first experiment:

$$\frac{a\,h\,p}{A\,H\,P} = 5.9431 \text{ lignes}$$

$$\sqrt{\frac{a\,h\,p}{A\,H\,P}} = 2.43 \text{ lignes}$$

$$v = V\sqrt{\frac{a\,h\,p}{A\,H\,P}} = 154. \text{ lignes} = 12 \text{ ins. } 10 \text{ lig.} =$$

velocity sought (1.14 ft., or c = 56.5).

And in making use of the second experiment:

$$\frac{a\,h\,p}{A\,H\,P} = 0.3886 \text{ lignes}$$

$$\sqrt{\frac{a\,h\,p}{A\,H\,P}} = 0.623 \text{ lignes}$$

$$v = V\sqrt{\frac{a\,h\,p}{A\,H\,P}} = 216 \text{ lignes} = 18 \text{ inches per second,}$$

the velocity sought, (1.599 feet; or c = 79.3).

This last result is perhaps too great. That of the first experiment is too little, for the reasons stated. It is certain that the velocity of the water in the projected channel will be at least a foot per second; its discharge, therefore, will be 27 feet 6 inches cubic per second; or multiplying by 150, will be 4125 water inches (33.3 cub. ft. per sec.), following the language of the "fontainiers."

It is therefore certain that such a channel will be more than sufficient, if it is not necessary to have more than two or three thousand water inches flow in it.

It will be observed that the velocity measured by a floating ball of wax on the surface, and presumably in the center of the current, was assumed to be the mean velocity of the stream.

It will also be observed that this report gives no formula of

the Chézy form, only a method of proportions. But in 1776 Chézy had already generalized his ideas on the subject. He then writes:

"*Formula to find the uniform velocity that the water will have in a ditch, or in a regular canal of which the slope is known, knowing also the cross-section of the body of moving water.* This being given:

Let h be the height of slope per toise (fathom) expressed in lignes of the King's foot. (That is, in lignes on 864 lignes.)

Let p be the length measured along the sides and bottom of the channel (wetted perimeter) in lignes.

Let a be the area of the cross-station expressed in lignes of square feet. (That is, in 1-144 parts of a square foot.)

Let v be the velocity sought.

We shall then have

$$v = 272 \sqrt{\frac{a\ h}{p}}$$

in lignes of the King's foot of space passed over in one second." (In English feet this reduces to $v = 57.3 \sqrt{r\ s}$).

"Much is to be gained," adds Chézy, "in locating summit levels of canals, from giving only a small fall to the summit feeder."

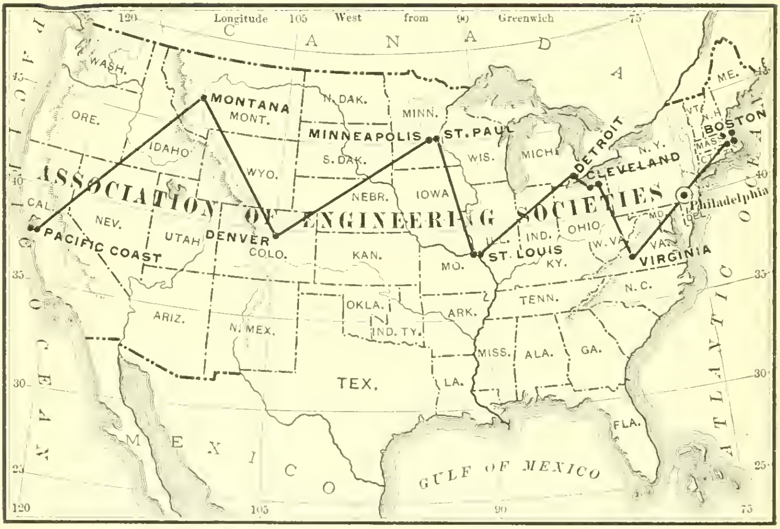
DISCUSSION.

Mr. Edmund B. Weston.—A few years ago, there could be found upon an old tomb in Flanders, the following inscription: "*Une heure viendra qui tout paiera,*" which, translated, reads: "An hour shall come that shall atone for all." If these words had been chiseled in commemoration of M. Chézy, it could be truly said that that which they prophesied had become true, and that the hour had long since arrived which atoned for the lack of appreciation accorded to this, now celebrated, savant, during his life. For few there are among the books and essays of the present day which treat upon the laws of the flow of water in channels and conduits, which do not contain the simplest of all forms of formulas, the Chézy formula.

It has often occurred to the writer from what he has known in regard to the origin of the Chézy formula, and it has been more vividly impressed upon his mind by reading the interesting paper by Mr. Herschel, that M. Chézy must have been a man of very superior ability to have been able to construct such a simple and useful form of formula, with so little experimental knowledge at his disposal. A form of formula that has been for more than one

hundred years extensively used as a hydraulic formula of the first rank, and even at this enlightened period of the world's progress, notwithstanding the large amount of experimental data which modern scientific investigators can make use of, the form of the Chézy formula still seems to be growing in popularity.

What little can be learned in regard to the professional career of M. Chézy, would imply that his worth was not recognized during his life. This may have been due to the unsettled state of affairs in Europe during the latter part of the eighteenth century, or it may have been that the results of the work with which he was identified were not in so great a demand during his life as after his death, and, consequently, did not become as well known to the world at large.



BRADLEY & POATES, ENGR'S N.Y.

Association of Engineering Societies.

Vol. XVIII. JANUARY, 1897. No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

446th Meeting, January 6, 1897.—The meeting was held at 1600 Lucas Place, with Vice-President Bryan in the chair, who called the meeting to order at 8.10 p. m. Twenty-four members and one visitor were present.

The minutes of the 444th and 445th meetings were read and approved. The Executive Committee reported the proceedings of its 225th, 226th, 227th, and 228th meetings.

Mr. J. A. Ockerson explained that two Belgian engineers, Messes.. J. A. Pierott and Henri Vander Vin, who had visited St. Louis for the purpose of examining dredge boats and river improvements, had been entertained at the expense of the club.

The names of Messsrs. C. E. Delafield, G. S. Montgomery, and A. L. McRae had been reported upon favorably by the Executive Committee, and these gentlemen were balloted for and elected to membership in the club.

The names of Messrs. W. H. Boehm, instructor in mechanical engineering, Washington University, and David R. Williams, mechanical superintendent, Planters Hotel, were proposed for membership and referred to the Executive Committee.

Mr. H. A. Wheeler stated that the National Brick Manufacturers' Association was soon to hold its convention in St. Louis, and suggested that the club tender the use of its rooms. The Secretary was instructed to write to the Association and make such an offer.

The paper of the evening, by Mr. F. F. Harrington, was then read. It was entitled "A New Testing Machine and the Cross Breaking Test of Vitrified Brick." The paper was illustrated by lantern slides, drawings, photographs, and broken specimens of paving brick. The testing machine was described, and the methods of calibrating the machine and determining its friction were explained. A number of tests of vitrified paving brick were given and broken specimens were exhibited. In conclusion, standard methods for making the cross breaking test of vitrified brick were proposed.

The Secretary announced that he had received the resignation of

Messrs. George F. Thompson, S. E. Johannsen, David Molitor, Chas. F. Muller, Kivas Tully, and C. H. Sharman.

There being no further business, the meeting adjourned.

RICHARD McCULLOCH, *Secretary.*

447TH MEETING, JANUARY 21, 1897.—The meeting was held at 1600 Lucas Place. President Flad was in the chair and called the meeting to order at 8.15 P. M. Thirty-four members and four visitors were present. The minutes of the 446th meeting and of the 230th meeting of the Executive Committee were read and, with some minor changes, were approved.

The name of Wm. H. Boehm, instructor in mechanical engineering, Washington University, had been reported upon favorably by the Executive Committee, and this gentleman was balloted for and elected a member of the club. The Secretary announced that he had received an application for membership from Mr. H. J. Pfeiffer, assistant engineer, Terminal Railroad Association of St. Louis. This application was referred to the Executive Committee.

The question of having a lunch at the meetings of the club was then taken up. A motion was made that at the next three meetings of the club a lunch be provided, to be paid for out of the general funds, the cost of each lunch not to exceed $12. This motion, after some discussion, was passed.

The paper of the evening, by Mr. J. A. Ockerson, entitled "The Problem of Deep Water Navigation Through the Passes from the Mississippi River to the Gulf of Mexico," was then read. The general nature of the Delta was described, the history of the methods of improvements was given, and the present method for the improvement of South Pass was shown. The effect of the deepening of South Pass was shown by the fact that during the last twenty years the number of vessels passing through had been increased only 10 per cent., while the tonnage had been more than trebled. The present contract for keeping open South Pass expires in 1899, and the paper showed the necessity for some immediate action to determine the best method of maintaining an outlet to the Gulf. An interesting discussion followed, participated in by Prof. Johnson, and Messrs. Holman and Robt. Moore. The paper was abundantly illustrated by maps, photographs, and lantern slides.

It was moved by Mr. Pitzman and seconded by Mr. Russell that a committee of five be appointed by the chair to prepare a memorial addressed to the Congressional Committee in charge of the appropriation bill, recommending that the appropriation bill for the improvement of Southwest Pass, now under discussion, be made to cover the survey of the entire Delta for the purpose of determining the best location for a deep water channel and the best method for its improvement; that a copy of the memorial be sent to each of our members in Congress, and that a copy be presented for indorsement to the Merchants' Exchange of St. Louis. The motion was carried and the president appointed the following gentlemen as members of the committee: Mr. Ockerson, chairman, and Messrs. Russell, Johnson, Holman, and Pitzman.

On motion, the Executive Committee was instructed to procure a better light for operating the stereopticon. There being no further business, the meeting adjourned.

RICHARD McCULLOCH, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., January 4, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 p. m. Present, sixteen members and three visitors. President Stevens in the chair. Minutes of previous meeting read and approved. The resignations of Mr. R. B. C. Bement and of Mr. R. Davenport were accepted. The Treasurer was authorized to pay the court house custodian $15.00 for care of Society library. The librarian was instructed to continue subscriptions for "Engineering News," "Engineering Record," "Engineering," and "Transactions of American Society of Mechanical Engineers." A preliminary report of the committee on the licensing of land surveyors was read and again referred to the committee, with recommendations to consult with similar committees of other bodies. Mr. Wm. C. Smith and Mr. Geo. Z. Heuston were elected to membership. The annual reports of the officers of the Society were read and accepted, and, by resolution, the incoming President was requested to audit the Treasurer's report. The annual election resulted in the following list of officers for the year 1897:

President: K. E. Hilgard.

Vice-President: Oliver Crosby.

Secretary: C. L. Annan.

Treasurer: A. O. Powell.

Librarian: A. W. Münster.

Representative on the Board of Managers of the Association of Engineering Societies: E. E. Woodman.

Vice-President Crosby took the chair, and Mr. L. W. Rundlett read a paper on the "Centerville Extension of the St. Paul Water Works," exhibiting maps, drawings, specimens of material, etc. The detail of conduit construction, the locations of mains, artesian wells and pumping stations and statements of quantities, cost, etc., were given.

A vote of thanks was awarded to Mr. Rundlett, and he was requested to prepare his paper for publication in the Journal.

C. L. Annan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, January 8, 1897.—Called to order at 8.30 p. m. by President Dickie.

The minutes of the last regular meeting were read and approved.

Application for membership by Harry H. Hirst, civil engineer, proposed by Frank Soulé, H. I. Randall, and Otto von Geldern, was read and referred to the Executive Committee.

The Nominating Committee made the following report, which was accepted and ordered to go to ballot:

To the President and Members of the Technical Society of the Pacific Coast:

Your Nominating Committee hereby place in nomination as officers for the ensuing year:

For President: E. J. Molera.

For Vice-President: W. F. C. Hasson.

For Secretary: Otto von Geldern.

For Treasurer: E. T. Schild.

For Directors: D. C. Henny, L. Falkenau, Hermann Barth, E. C. Jones, and G. W. Percy.

Very respectfully,

C. E. Grunsky, *Chairman of Nom. Com.*

It was moved that the paper by Mr. Dickie, entitled "Industrial Education," be again read, in order to give the members present an opportunity to discuss it properly.—Carried.

The President thereupon read the paper, which was discussed by Professors Marx, Cory, Soulé, Wing, and others. Mr. L. A. Buchanan read an abstract from a paper prepared by him on the same subject.

Adjourned.

Otto von Geldern, *Secretary.*

Annual Meeting, held January 22, 1897.—Called to order by D. C. Henny.

C. E. Grunsky and Hubert Vischer were appointed tellers to count votes. Thirty-nine votes were cast for the regular ticket, which was elected as follows:

President: E. J. Molera.

Vice-President: W. F. C. Hasson.

Secretary: Otto von Geldern.

Treasurer: E. T. Schild.

Directors: Herman Barth, Louis Falkenau, David C. Henny, Edward C. Jones, G. W. Percy.

The annual reports of the Secretary and Treasurer were read, received, and placed on file.

Meeting adjourned.

Otto von Geldern, *Secretary.*

Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club, of Cleveland, at their rooms, Case Library Building, January 12, 1897. President Howe in the chair. Present, forty-two members and twenty-two visitors.

The minutes of the regular meeting, December 8, and the semi-monthly meeting, December 22, 1896, were read and approved. Messrs. Wm. Secher and A. A. Skeels were appointed tellers to canvass the ballots of Messrs. Sawtelle, Leeper, Ives, Thayer, Otis, and Mills. The Executive Board announced the approval of the application of Messrs. P. L. Cobb and R. H. Fernald for active membership, and their applications were read. The board reported also the admission to the Association of Engineering Societies of the Detroit Society of Civil Engineers, a society containing eighty-seven members.

Mr. Searles reported verbally for the committee on the Cleveland Academy of Science, referring to the Prospectus of the Academy, which has been distributed, and upon motion, his report was received. After some general discussion by the club, the following resolution was offered by Mr. Searles:

Resolved: That a committee of seven be appointed by the President

to meet in convention with committees appointed from the various other societies for the purpose of discussing the policy of the Academy of Science and of reporting to the club. Amended, to add four members to the present committee of three, and adopted. Messrs. Jos. L. Gobielle, C. M. Barber, Ambrose Swasey, and A. H. Porter were announced as the four additional members.

Upon motion of Mr. Searles that a commmittee on nomination of officers for the ensuing year be elected, the following members were nominated: Messrs. Ambrose Swasey, Wm. H. Searles, Jos. L. Gobielle, W. R. Warner, A. H. Porter, C. H. Benjamin, and Chas. W. Howe. Messrs. Hyde and Barber were appointed tellers.

Then followed the talk of the evening, by Mr. S. T. Dodd, upon the "Plant of the Niagara Falls Electric Power Company," their method of generating power and the various industries in which it is utilized. It was listened to with great interest and was followed by interesting remarks on the same subject by Prof. C. H. Benjamin and Dr. Jno. W. Langley, and others.

The following were announced elected members of the Committee on Nomination of Officers: Messrs. Ambrose Swasey, A. H. Porter, Jos. L. Gobielle, Wm. H. Searles, and W. R. Warner.

After the meeting a light lunch was served.

F. A. Coburn, *Secretary.*

Case Library Building, Cleveland, Ohio., January 27, 1897.—A semi-monthly meeting of the Civil Engineers' Club of Cleveland was held in the rooms of the Club, Case Library Building, Tuesday evening, January 26, 1897. President Howe in the chair. Present, 30 members and 14 visitors.

The paper of the evening, by Joseph R. Oldham, N. A. and M. E., on "Resistance of Ships and Other Floating Bodies at Deep and Shallow Drafts of Water," was read and was listened to with interest. The following subjects were touched upon:

"Shallow-Draft Yachts," "Water Pressure in the Deep Oceans," "Resistance of Fishes and Fish Torpedoes," "Friction in a Perfect Fluid," "Friction of Solid Bodies," "Screw and Side Wheel Engine Friction," "Resistance of a Plane Passing Through Water," "Speed of Torpedo Boats and Deep Draft Steamers."

Messrs. Gobielle, Raynal, and others assisted in an interesting discussion.

After the meeting a light lunch was served.

F A. Coburn, *Secretary.*

The Montana Society of Civil Engineers.

The members of the Montana Society of Civil Engineers visited the Anaconda company's coal mines at Belt, January 8th. They were met there by P. C. Kittle, general manager; W. D. Mulloy, the master mechanic; F. W. C. Whyte, the engineer, and others of the company, and through their kindness were given an opportunity to make a thorough inspection of the works.

Only those who have visited Belt recently have any idea of the magni-

tude of the mine. Through one adit, with but a slight incline, all the coal of the mine is brought to the surface, the daily output averaging 3,200 tons, 350 tons being coking coal taken from the lower portion of the coal seam, which is kept separate as it comes from the mine. The remainder is lump coal, which is dumped directly into cars for shipment, passing over screens in the process of dumping, thus separating the slack coal. There are about 650 tons of the slack coal, which, together with the 350 tons of coking coal, go through the washing process. The Lurich system of washing is used. The slate, sulphur balls and inferior coal are removed by a sort of jigging process, the coal floating and the rock and impurities dropping to the bottom.

After going through that process the coal goes to the coking ovens. There are 100 beehive ovens in constant use, turning out 100 tons of coke daily. The three Phillips automatic car tips, which dump all the coal that comes from the mine, are interesting to examine. In ten hours 3,200 tons of coal are dumped. By means of a tag placed upon each car it is known who mined it, and the part of the mine it is from. A thorough and complete system of weighing is used, keeping accurate account of the coal mined by each miner. In the mine 34 Ingersoll-Sergeant mining machines are constantly working, undercutting the coal.

The business meeting of the society was called to order in the private dining room of the Park hotel this morning by President Herron. The first business transacted was the election of the following officers: President, Charles W. Goodale; first vice-president, A. E. Cumming; second vice-president, Maurice S. Parker; secretary and librarian, A. S. Hovey; treasurer, James S. Keerl; trustee, F. W. Blackford; member of Board of Association of Engineering Societies, J. S. Keerl. John Herron, the retiring president, then delivered the annual address. At the conclusion of the address the new officers were installed and then the following resolution was adopted:

"Be it *Resolved*, By the Montana Society of Civil Engineers, that it extends the heartiest congratulations to Hon. Robert B. Smith upon his assumption of the reins of government of the state of Montana, and expresses the hope that during his administration the engineering profession may receive that fitting recognition in the conduct of public affairs which its importance and usefulness to the proper development of the resources of the state would appear to demand."

Finley McRae was appointed a committee of one to present the resolution to the governor, and to urge upon the executive that the society be recognized in the appointment of the irrigation commission, the state land agent and other commissions bearing on public works.

After a general discussion in regard to society matters the meeting adjourned until 8 o'clock this evening, and this afternoon the members visited the smelting, refinery, water power and electric light plants, where several hours were spent.

The meeting reconvened in the parlors of the hotel this evening and papers were read by C. W. Goodale and Maurice S. Parker.

A resolution was introduced and seconded by two-thirds of the members present to change the name of the society to "Montana Society of Engineers," and the secretary was directed to send out the usual letter ballots. After a general discussion lasting two hours the meeting adjourned

and the members of the society were escorted to the dining room, where an elegant banquet was served. Covers were laid for 50 guests and every chair was occupied by members of the society and invited guests.

After an hour spent in the discussion of the elaborate menu card Toastmaster Parker called the assemblage to order and the toast "Our Guests" was responded to by Charles W. Goodale; "The Press," by O. S. Warden; "The Montana Society of Civil Engineers," John Herron; "Electrical Engineering with Relation to Civil Engineering," John T. Morrow; "Mines and Miners," W. S. Thomas; "Our Wives and Sweethearts," Finley McRae; "The Engineer as a Mine Manager," Walter S. Kelley.

The banquet lasted until midnight, when an adjournment was made Adieus were said and many of the visitors took the southbound train for their respective homes.

ALBERT S. HOVEY, *Secretary.*

Denver Society of Civil Engineers.

DENVER, COLO., January 12, 1897.—Regular meeting called to order at 8.20 P. M., President Campbell in the chair. Minutes of last regular meeting were read and approved. The Secretary reported the receipt of a copy of the proceedings of the annual meeting of the American Society of Irrigation Engineers, held in Denver, December 11 and 12, 1896. A communication from Geo. L. Wilson, of a committee of the Civil Engineers' Society of St. Paul, regarding the examination and licensing of civil engineers and surveyors, was read, and the Secretary was instructed to reply that no such legal requirements existed in this state, except as it might apply to United States Deputy Mineral Surveyors.

A letter was also read from the Secretary of the Engineers' Club of St. Louis, regarding an amendment to their by-laws adopted some time since, in the matter of exchange of members in the Association, which was considered and discussed at length by all the members present. A resolution amending the by-laws of the Denver Society of Civil Engineers, in accordance with those of the Engineers' Club of St. Louis, was presented. The Secretary and Treasurer read his report for the year 1896, showing the Society to be in good financial condition, and he received a vote of thanks from the Society.

The Librarian read a very complete report, suggesting several improvements to the library in the matter of indexing, etc., and he also received a vote of thanks.

After the canvas of the ballot, the following officers were found to be duly elected for the year 1897:

President: R. A. Wilson.

First Vice-President: A. I. Fonda.

Second Vice-President: Wm. Ashton.

Secretary and Treasurer: Walter Pearl.

Librarian: Geo. H. Angell.

Executive Committee: Donald W. Campbell, Prof. P. H. Van Diest, Wm. B. Lawson.

The retiring President, Mr. Campbell, read a very able address, entitled "Professional Spirit," which was received with much interest by all present.

Next in order, President-elect Wilson was escorted to the chair by the

retiring President, when he made a few interesting remarks. His example was followed by other newly-elected officers present.

The retiring President was tendered a vote of thanks by the Society for the able manner in which he had presided during the year past. On motion the President was elected Manager for the Denver Society of Civil Engineers in the Association of Engineering Societies.

Adjourned at 10 P. M.

WALTER PEARL, *Secretary.*

Engineers' Club of Minneapolis.

MINNEAPOLIS, Minn., January 26, 1897.—The annual meeting was held in the City Engineer's office, City Hall, at 8 P. M.

President F. W. Cappelen in the chair .

A communication was read from Edward Flad, President of the Engineers' Club of St. Louis, enclosing a copy of bill H. R. 9492 and a memorial to Congress signed by a special committee of his club.

It was moved and adopted that a committee consisting of the President, Secretary and W. R. Hoag be appointed to draft a memorial to Congress agreeing in general terms with the one from the St. Louis Club, and that they at once forward the same to our Senator and Representative in Congress.

G. D. Shepardson called the Club's attention to the fact that there were before Congress bills relating to land-grant colleges, experimental working stations, and endowment for engineering experiments, which were of general interest to members of our profession and that these bills had more valuable points than any before introduced.

A motion was adopted appointing Geo. D. Shepardson, W. R. Hoag, Frank H. Constant and F. W. Cappelen a committee to draw a memorial to be at once forwarded to Congress, in favor of bills H. R. 5836, introduced by Hon. D. K. Watson, of Ohio; H. R. 6432, by Hon. A. G. Dayton, W. Va., and S. 2301, by Hon. Eugene Hale, Me.

A motion was adopted that the President appoint a committee on new membership.

The Secretary reported that the club had held six meetings during the past year, at which five papers had been read, and that three members had been added to the club.

The Treasurer's report showed that all indebtedness of the club had been paid.

Receipts:—

Balance on hand last report	$16.52	
Received from members	3.00	
Received from subscription to pay debt	77.28	
Total		$96.80

Expenditures:—

Paid balance JOURNAL on account	$77.28	
Postage and notices	10.60	

Total	87.88
Balance on hand	$8.92
Received and paid for 1896 JOURNAL	$36.00
Received from members for 1897 JOURNAL A. E. S.	12.00
Assets:—	
Reported last year	$95.00
Paid as above	3.00
Balance due club	$92.00

NOTE.—Of this amount, $57.00 cannot be collected, as those owing it are out of funds or have left Minneapolis, leaving a balance of $35.00 which possibly will be paid.

ELECTION OF OFFICERS FOR 1897.

On an informal ballot for President, Mr. Cappelen received a majority of the votes cast. He then withdrew his name, stating that he much preferred some one else might have the honor of being President; that as a member he would do all he could for the success of the club.

The following were then elected:—

President—Frank J. Llewellyn.

Vice-President—Irving E. Howe.

Secretary and Treasurer—Elbert Nexsen.

Librarian—A. B. Coe.

Member Board of Managers Association of Engineering Societies—George D. Shepardson.

W. R. Hoag then read the paper of the evening on "An Engineer Abroad." It being quite late, he cut his paper considerably, and at the close he was requested to continue the subject at the next meeting, to which time the discussion was postponed.

Adjourned.

ELBERT NEXSEN, *Secretary.*

Boston Society of Civil Engineers.

JANUARY 12, 1897.—A special meeting of the society was held in Chipman Hall, Tremont Temple, Boston, at 8 P. M., President George F. Swain in the chair. Total number present, including ladies, 270. The members of the New England Water Works Association and of the Massachusetts Highway Association were invited to join in this meeting, and many accepted the invitation.

Professor Alfred E. Burton gave a very interesting account of the expedition made last summer to Umanak Fjord, West Greenland. The lecture was very fully illustrated by lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary.*

JANUARY 27, 1897.—A regular meeting of the society was held in Chipman Hall, Tremont Temple, Boston, at 7.50 P. M., President George F. Swain in the chair. 135 members and visitors were present.

The records of the last regular meeting and of the special meeting of January 12 were read and approved.

Messrs. Greely, S. Curtis, Jr., Dana Libbey, Otis D. Rice, George O. W. Servis, and Frank H, Stephenson were elected members of the society.

The following committee was chosen to nominate officers for the ensuing year: L. F. Rice, C. H. Swan, A. L. Plimpton, W. E. Foss, and C. W. Sherman.

Mr. Henry Manley was appointed to make the necessary arrangements for the annual dinner.

Mr. E. W. Howe read a memoir of William A. Allen, a member of the society, prepared by a committee appointed for the purpose, and Mr. George A. Kimball read a memoir of Past President Albert F. Noyes.

On behalf of the donors, Mr. Fitzgerald presented to the society a large crayon portrait of Past President Noyes.

Mr. Howard A. Carson read the paper of the evening, entitled "Various Inventions and Devices for Building Tunnels and Passageways under Rivers and Other Bodies of Water," which was profusely illustrated by lantern-slide views.

Adjourned.

S. E. Tinkham, *Secretary.*

Albert Franklin Noyes.—A Memoir.

By George A. Kimball and Henry D. Woods, Committee of the Boston Society of Civil Engineers.

[Read before the Society, January 27, 1897.]

Albert Franklin Noyes, the son of George F. Noyes, was born in Boston in 1850. The family soon removed to Melrose, where Mr. Noyes was educated in the public schools. He later entered the Lawrence Scientific School, Harvard University, Cambridge. During the years of 1871, '72 and '73, he was employed by Ernest W. Bowditch and Charles H. Bateman in topographical surveys and landscape work. He was also engaged on some railroad surveys on Shelter Island, N. Y. In April, 18;4, he entered the office of Frederic Schoff, City Engineer of Newton.

In April, 1876, he was appointed Acting City Engineer of Newton, and from that time on exerted all his energies in developing the usefulness of the office, and carrying forward, to the best of his ability, all the various improvements that were projected from time to time in the city. On Janu- 15, 1877, he was confirmed City Engineer in full charge of the office, and was reappointed each year until the new city charter was adopted, in 1882, which made the appointment a permanent one, so that his last appointment was in January, 1883, as City Engineer of Newton.

When he first came to the office, the work required of the department consisted mainly in giving lines and grades for streets and for laying water pipe and making such surveys relative to city property as might be required by the Assessors and other departments of the city, and but two assistants were employed. As the city developed, the calls on the Engineer's Department became much more varied. New work, consisting of water works, parks, improvement of highways, etc., was undertaken by the city. When it became necessary to increase the permanent force of the office, Mr.

Noyes found that much better satisfaction could be obtained from young men who had already had some experience in outside work, and he endeavored, as far as possible, to give employment, during the summer vacation, to as many scholars as could be employed conveniently on the survey parties. In this way, many who had the taste for the work have spent their summer vacations in the Newton office, and have either taken up engineering work and remained in the Newton office, or have entered other offices. It was always Mr. Noyes's pleasure to follow these students in their business career and to help them with advice and recommendations whenever he could.

In 1880, in connection with work at the Water Works Pumping Station, Mr. Noyes applied the system of driven pipe wells, attached to a pump, for the purpose of lowering the ground water trenches excavated in water-bearing gravel and fine sand or even quicksand.

In 1882 he was appointed Inspector of Plumbing by the Board of Health, and in this connection made a sanitary survey of the whole city, and formulated modern rules and regulations for house plumbing. In 1882 and '83 the heating and ventilating systems in several of the largest schools were reconstructed and the sanitary condition improved according to plans made by Mr. Noyes, and the work was executed under his direction.

In connection with his work on the highways, he designed a system of highway book-keeping, by which all expenditures are charged up to the various pieces and classes of work so that the cost of each improvement can be directly ascertained, and the data can be used as a basis for making estimates for proposed work.

In 1884 he commenced a study of the sewer requirements of the city, and in 1887 visited and examined the sewers and sewerage disposal systems in use at East Orange, Long Branch, Atlantic City, N. J., Pullman, Ill., Bryn Mawr and Wayne, Pa.

In 1887 he reported to the city government on the method of improving Laundry Brook, one of the main brooks passing through the city, which at certain seasons of the year overflowed its banks and flooded large portions of low lands.

In connection with Alphonse Fteley as consulting engineer, he reported in 1889 on an additional water supply for the city of Newton, taken from underground sources; also for a high service system. In 1891 the work on the additional water supply was undertaken and a wooden filtering gallery constructed along the bank of Charles River, and a covered masonry reservoir, the first built in this vicinity, was constructed on Waban Hill to receive the ground water from this supply.

In the latter part of 1890 he made a report to the city government on a complete system of small pipe sewers for the whole city of Newton, comprising some 130 miles, at an estimated average cost of $2.56 per running foot. The outlet of this system was into the Charles River system of the Metropolitan sewer. Previous to this and before the Metropolitan sewer had been finally decided upon, Mr. Noyes had reported on a system of disposal by chemical treatment and filtration, with an outlet into the Charles River. Some forty or fifty miles of sewers were built under Mr. Noyes's administration and according to his plans, which included a system of sub-drains laid below the sewers for the purpose of removing any accumulation of ground water which might otherwise percolate into the sewer. The sew-

ers were designed to carry only house drainage, all surface water to be carried off in surface drains built on an entirely different system. Mr. Noyes also inaugurated the use of T-branches for house connections in the sewer. In visiting various localities he found that the small flow passing from each house connection into the sewer did not in any way obstruct the flow of the sewage in a separate system. All house branches being from four to six inches in diameter and the smallest sewers being 8", the flow from the houses would usually fall from the branch into the sewer flow, and the theoretical flow of this current into the sewer at an obtuse angle did not in practice have any effect on the current in the sewer.

In 1892, with the assistance of Mr. Edward Buss, C. E., of Boston, Mr. Noyes made a complete report on a system of surface drainage for the whole city, including proposed improvements of all the natural water courses, recommending their acquisition by the city, and their improvement by means of driveways or parkways on either side. Nearly one mile of the valley of the lower Cheese Cake Brook was straightened and laid out as a parkway some 120 feet wide, the brook running through the centre at the foot of easy slopes covered with grass and driveways on each side.

In 1893 a special committee appointed by the city, consisting of Albert F. Noyes, Charles A. Allen and George S. Rice, reported on plans for the abolition of sixteen grade crossings on the Boston & Albany Railroad in the city of Newton. The same year plans were prepared for several miles of boulevard projected by a syndicate which offered to furnish the land and give financial assistance towards the accomplishment of the work, but on account of legal questions the work of construction was delayed until after Mr. Noyes's resignation as City Engineer.

Mr. Noyes entered the service of the city of Newton at the age of twenty-five and continued in it for eighteen years, sixteen of which he occupied the office of City Engineer. He designed and executed nearly all its public works, and was to Newton an able engineer and a public spirited citizen. The results of his work on the additional water supply, improvement of highways and the construction of the sewer system were all considered by the engineering profession as models, and were frequently examined by other engineers interested in similar work.

The work that he executed in Newton shows that it was all the result of thorough research and careful study. It was in many instances original with its author, who did not hesitate to depart from well-known customs, if, after careful investigation and inquiry, he was satisfied that better results could be obtained. His annual reports are full of valuable information, and his faithful work in Newton made him a leader in municipal engineering in this vicinity.

In 1893 the State Board of Health was directed to investigate and report upon the question of a Metropolitan water supply, and on account of Mr. Noyes's knowledge and experience in the matter of water supply and sewerage systems, and particularly in the matter of water supplies taken from the ground, he was offered the position of Assistant Chief Engineer. In this position, where it would be his duty to examine and report on new systems of water supply and sewerage submitted to the Board, and to make investigations connected with the Metropolitan water supply, he saw a much larger field for study and usefulness, and resigned his position as City Engineer of Newton July 24, 1893, much to the regret of the citizens

of Newton. During the next two years he reported to the Board upon the water supply or sewerage of some fifty places in Massachusetts, besides making reports upon various matters connected with the Metropolitan water supply.

Mr. Noyes was appointed by the Governor as a member of the Metropolitan Sewerage Commission for three years, commencing January 7, 1895, and held the position at the time of his death. This appointment was especially appropriate, as his experience as an engineer, his study of numerous sewerage problems and his executive ability fitted him for dealing with questions coming before the Commission.

In 1895 he was elected to the Board of Aldermen of Newton and was made chairman of the Sewer Committee, one of the highway surveyors and a member of the joint commission appointed to revise the city charter. From the time of his election until his death he spent many hours looking after the various city interests coming up before the Board, especially in connection with the sewer department and the revision of the city charter. His familiarity with all the departments of the city made him a valuable member of the Board. His counsel was eagerly sought by his fellow members and fully appreciated by the citizens of Newton.

He closed his connection with the State Board of Health in 1895 and opened a private office in partnership with Mr. Allen Hazen, making specialties of water and sewerage works. The firm was connected with water supply problems in Austin, Tex.; Far Rockaway, L. I.; Menominee, Mich.; Columbus, Cleveland and Painesville, O.; Harrisburg and DuBois, Pa.; Jersey City, N. J.; Ashland, Wis.; Indianapolis and Princeton, Ind.; Greenfield, Munson, Lynn, Newburyport, Adams and Lawrence, Mass., and Hartford, N. Y. In sewerage work it was connected with the design or construction of sewer systems in Altoona, Pa.; Plainfield, N. J.; Vassar College, Poughkeepsie, N. Y.; Spencer, Quincy and Melrose, Mass.

Whenever Mr. Noyes was called upon for a report on matters with which he was not perfectly familiar, he availed himself of all means accessible to gain the required knowledge, and was careful to look up the best authorities having the special knowledge required outside of his experience, and to advise with them before settling on a definite opinion. He was always genial, generous and kind to a fault. He would listen patiently to all grievances and always endeavor to explain all apparent wrongs which might have grown out of public improvement. He was an able-minded, conscientious public official, and a scrupulously exact servant to the city and commonwealth. He had a wide circle of friends and acquaintances who held him in high regard.

Mr. Noyes always took a lively interest in our society and frequently took part in the discussions. He was librarian of the society in 1885 and '86, vice-president from March, 1892, to March, 1894, and president of the society from March, 1895, to 1896, and his faithful work in arranging our new and commodious quarters is fully appreciated. The older members of the society remember him as a pleasant and genial companion, and many of the younger members will never forget his kindly interests in their welfare and his willingness at all times to give them such information and advice as would advance them in their profession. He contributed the following papers to this society:

"The Heating and Ventilating of School Buildings."

Read June 18, 1884. (Not printed in JOURNAL.)

"Description of the Foundation placed beneath the Pumps and Engines at the Newton, Mass., Pumping Station."

Read February 18, 1885. Printed in the JOURNAL, Vol. IV, p. 213.

"Description of Newton, Mass., Water Works."

Read October 15, 1890. (Not printed in JOURNAL.)

"Discussion on Roads and Road Building."

Read November 19, 1890. Printed in JOURNAL, Vol. X, p. 244.

"Relation of the Engineer to His Assistants and Subordinates."

Read March 15, 1893. Printed in the JOURNAL, Vol XII, p. 447.

"Organization and Management of a City Engineer's Office."

Read December 20, 1893. Printed in the JOURNAL, Vol. XIII, p. 541.

"Annual Address on Retiring from the Presidency of the Boston Society of Civil Engineers." Delivered March 18, 1896. Printed in the JOURNAL, Vol. XVI, p. 46 of Proceedings.

Mr. Noyes joined the American Society of Civil Engineers in 1884, and endeavored to attend the annual meeting and also the conventions, where he always felt that he could gain much useful professional information as social pleasure.

He was President of the New England Water Works Association in 1890 and '91, and contributed the following papers to the Association:

"Weight of Cast-Iron Pipe for all Sizes and Pressures."

Read June 19, 1885. Printed in the Transactions of the N. E. Water Works Asso. for the year 1885, p. 154.

"Driven Wells as a Means of Water Supply."

Read March 9, 1887. Printed in the Journal, N. E. W. W. Asso., Vol. I, 4, p. 19.

"Experience in Excavating in Quicksand."

Read March 12, 1890. Printed in the Journal, N. E. W. W. Asso., Vol. IV, p. 218.

"President's Annual Address."

Read June 10, 1891. Printed in the Journal, N. E. W. W. Asso., Vol. VI, p. 5.

He was Vice-President of the Massachusetts Highway Association at the time of his death.

He was regarded as one of the foremost authorities in the matter of water supplies, and always showed excellent judgment and remarkable ability in planning the various works with which he has been connected. He was an inveterate worker, and his sudden taking away was due, in a great measure, to overwork and disregard for his health and strength. He died suddenly of heart failure on October 12, 1896, as he was taking the train at the Providence depot for a business trip to Dedham. He leaves a widow, one son, and two daughters.

Association of Engineering Societies.

Vol. XVIII. FEBRUARY, 1897. No. 2.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club of Cleveland, Tuesday evening, February 9, 1897, in the rooms of the club, Case Library Building, President Howe in the chair. Present, forty-seven members and twenty-five visitors.

The minutes of the last two meetings were read and approved. Messrs. Palmer and Fairfield were appointed tellers to canvass ballots for the election of Messrs. P. L. Cobb and R. H. Fernald to active membership.

The Executive Board reported an application by various members for the election of Dr. Edward W. Morley to honorary membership. It had been approved by the board, and read as follows:—

It being the policy of the Civil Engineers' Club to choose its honorary members from among those who have won distinction in engineering, architecture, and applied science, and having in our midst one who, by his original research and experiment in scientific lines, has obtained results of such consummate accuracy that he is classed among the most eminent scientific men of the world, therefore we, the undersigned, believing that he will greatly appreciate the honor, respectfully recommend that Dr. Edward W. Morley be elected honorary member of this club.

Ambrose Swasey,
William H. Searles,
James Ritchie,
Aug. Mordecai,
F. A. Coburn,
S. T. Wellman,
John L. Culley,
A. Lincoln Hyde,
Worcester R. Warner,
Cady Staley,
Dayton C. Miller.

The applications of the following for active and associate membership had been approved by the board: Messrs. William B. Hanlon, Louis C. McClouth, William E. Reed, John Perry Johnston, Philip E. Knowlton, Edward E. Rose, and Charles Goffing to active membership, and William Oehlstrom to associate membership.

The report of the board was adopted.

The Nominating Committee reported through Mr. Searles, the chairman being absent, the following officers for the coming year:—

For *President*—James Ritchie.
Vice-President—C. M. Barber.
Secretary—F. A. Coburn.
Treasurer—Hiram Kimball.
Librarian—A. Lincoln Hyde.
First Director—J. W. Langley.
Second Director—W. C. Jewett.

The report of the committee was adopted.

The committee appointed at the last meeting in relation to the Academy of Science reported as follows:—

They had met with gentlemen of other societies and heard of reports of progress made. It was the sense of the committee that it was not now in the interest of the club to pursue this matter further.

The report of the committee was adopted and the committee discharged.

Professor Charles H. Benjamin, of the Case School of Applied Science, read the paper of the evening upon "Applications of the Electric Motor in Machine Shops," which was listened to with great interest. An interesting discussion followed, in which Messrs. John W. Langley, R. L. Newman, George Bartol, S. T. Dodd, and others participated.

Upon motion, the President appointed the following committee to make arrangements for the banquet: Chairman, Joseph Leon Gobielle; E. A. Sperry, A. Lincoln Hyde, F. M. Comstock, S. T. Dodd, J. G. Oliver, F. A. Coburn.

Messrs. Fernald and Cobb were reported as elected to active membership in the club, and the meeting adjourned. After the meeting a light lunch was served.

F. A. Coburn, *Secretary*.

A semi-monthly meeting of the Civil Engineers' Club of Cleveland was held in the rooms of the club, Case Library Building, Tuesday evening, February 23, 1897, President Howe in the chair. Present, sixty-one persons, of whom about forty-three were members.

Dr. Cady Staley, President of Case School of Applied Science, presented a paper upon "The Sanitation of Paris: Its Water Supply, Street-cleaning, Sewers and Sewage Disposal, the Sewage Farm at Genevilliers." It was a very interesting talk, and was attentively listened to by all present. In the animated discussion that followed, Messrs. Force, McGeorge, Searles, and Parmeley took active part.

After the meeting a light lunch was served.

F. A. Coburn, *Secretary*.

Civil Engineers' Society of St. Paul.

February 1, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at the Society room; 16 members and 7 visitors in attendance.

President-elect Hilgard called the meeting to order at 8.15, and inaugurated himself by a few advisory remarks.

Minutes of the previous meeting were read.

The committee on licensing land measures reported a bill and was in-

structed to refer the same to the Ramsey county delegation. The Society declared itself favorably inclined to such a bill as a step in the right direction.

The matter of improved road laws was introduced by Professor Hayes, of the State Agricultural Experimental Station, and Mr. Choate, a Minneapolis attorney, who has given the subject much study for the past five years. Both were agreed on a conservative policy inasmuch as the farmers generally seemed opposed to much outlay in this direction, as the cost must fall principally on them, and the benefits largely accrue to engineers and bicyclists. Mr. Choate pronunced the present State road laws a hodge-podge of inharmonious acts with which few of the present legislators were conversant. He advocated immediate steps toward an amendment to the State Constitution which should provide for a road fund and formulate a system of road improvement. A fund is a prime necessity inasmuch as the only available fund at present is the Internal Improvement Fund, raised from the sale of lands donated to the State by the United States, and which, though now at a maximum, does not realize more than $25,000 per year. This fund is at present disbursed where it will cut the greatest dash politically.

Mr. Choate's amendment proposes a fund which shall be pro rated, similarly to the State school fund, and he assumes that it may be supplied by an inheritance tax, and by collecting the taxes which telephone, express, sleeping car, and other companies ought to pay. Two years must pass before such an amendment, if now introduced, could be approved by the people. In the meantime he advises the appointment of a temporary highway commission whose duty it shall be to study the existing systems in other States, to examine road material in various parts of the State, to inquire into methods of construction, to consider the matter of convict labor in connection with road building, and, in fact, to educate themselves thoroughly with a view to offering practical suggestions for the disposal of the fund when it shall become available. Meanwhile the State Road organization, the Farmers' Institute, and State School of Agriculture will be educating the people on the same subject.

Mr. Choate's suggestions met with the unanimous approval of the Society, and the Secretary was instructed to inform the Ramsey county delegation individually of this fact.

County Surveyor Forbes submitted a list of photographs showing the contrast between road improvements in Dakota county made by statutory labor, and those performed under contract for the same cost. The difference was striking and much in favor of the contract system.

President Hilgard appointed the following standing committees: Highways, J. D. Estabrook, C. F. Loweth and George L. Wilson. Railroads, W. L. Darling and E. E. Woodman. Street Railways, Oliver Crosby and H. E. Stevens. Examining Board, C. L. Annan, H. E. Stevens and Archibald Johnson.

A communication from the Engineers' Club of St. Louis, relative to the improvement of the Southwest Pass was referred to Mr. Stevens and Mr. Powell.

Robert Herzog was elected to membership.

At 10.30 P. M. the meeting adjourned to the Germania Café on invitation of the President and Vice-President.

C. L. ANNAN, *Secretary.*

Montana Society of Engineers.

THE regular monthly meeting of the Montana Society of Engineers was held in the former Board of Trade rooms Saturday, February 13, 1897. Called to order at 8 P. M.

There were present A. E. Cumming, presiding; James M. Page, Finlay McRae, J. S. Keerl, A. S. Hovey and a number of visitors.

The minutes of the annual meeting at Great Falls, which were read and approved, contained a full report upon the Anaconda Company's coal mine at Belt, furnished by F. W. C. Whyte, the engineer of the mine.

M. S. Parker, the engineer in the construction of the Black Eagle Falls dam, gave by request a full description of the dam and power houses, the Boston and Montana Company's smelter and electrolytic refinery and nature's works visited by the Society. Referring to the dam he stated that the original height of the falls was 25 feet, the present head with the dam 43 feet, and the flow of water at the minimum stage about 4,000 feet per second. About 20,000-horse power could be generated by the present development, he said. There is being used at present about 10,000 horse-power, of which the Boston and Montana Company use about three-quarters. He stated that the flow of the Giant Spring is about 500 cubic feet a second. The Spring is thought by many to be the outlet of the Belt River, which sinks 12 or 15 miles from there. The Spring is in the bank of the Missouri River, about one and a half miles below the dam, close to the United Smelting and Refining Company's smelter. About two miles below the Spring are the Rainbow Falls, the most beautiful of the Missouri River falls, which has a crest width of about 1,100 feet, and a sheer drop of 50 feet.

Applications for membership were read. There will be eight to be voted upon at the next meeting. The canvass of votes showed the following additions to the membership: Howard A. Fitch, Guy M. Kerr, J. H. Kerr, Ernest W. King, Andrew Rinker, T. M. Ripley and Walter H. Weed.

Of the 40 votes cast only 37 voted upon the amendment to the constitution, 33 for the amendment and four against.

The President announced the amendment carried.

The amendment changes the name of "The Montana Society of Civil Engineers" by eliminating the word "civil."

A motion was carried authorizing the publication of the constitution and by-laws and list of members.

The Secretary reported that payments should be made promptly to the Association, but the dues from members came in slowly.

A. S. HOVEY, *Secretary.*

Engineers' Club of St. Louis.

448TH MEETING, FEBRUARY 3, 1897.—The meeting was called to order at 8 P. M. at 1600 Lucas Place, with President Flad in the chair. 32 members and 7 visitors were present.

The minutes of the 447th meeting and of the 231st meeting of the Executive Committee were read and approved.

The name of Mr. H. J. Pfeifer, Assistant Engineer Terminal Railroad Association, having been reported upon favorably by the Executive Committee was balloted upon and this gentleman was elected to membership.

Mr. J. A. Ockerson, as chairman of a special committee, reported that a memorial regarding the improvement of the Delta of the Mississippi River had been prepared and sent to the various Engineering Societies and members of Congress from St. Louis. The committee having completed its work was discharged. In this connection the President reported that he had received favorable replies from several of the Engineering Societies and from Congressmen Cobb and Bartholdt.

A letter from the Association for the promotion of International Arbitration was read and on motion filed.

The Secretary reported that the library had been presented with a copy of the fifteenth annual report of the American Street Railway Association.

Professor F. E. Nipher then addressed the club on "The Frictional Effect of Trains of Cars on the Air." The instruments and methods used in measuring pressures in the neighborhood of moving trains were described. A diagram containing the results of a large number of tests was shown and the nature and equation of the curve deduced. The value of the constants computed from the equation of the curve and those computed from the observations checked closely. Improved instruments for making these tests were shown and future work in this direction outlined. The address was illustrated by apparatus and diagrams. The discussion which followed was participated in by Professor Johnson and Messrs. Flad, Ockerson, Bryan, Barth, Van Ornum and Baier.

The President announced that he had appointed Messrs. Maltby, Freeman and Harrington members of a reception committee to introduce new members.

There being no further business, the Club adjourned to another room where refreshments were served.

Richard McCulloch, *Secretary.*

449th Meeting, February 16, 1897.—The meeting was called to order at 8 p. m. at 1600 Lucas place, with President Flad in the chair. In the absence of the Secretary, Mr. W. A. Layman was appointed to fill that position. 22 members and 3 visitors were present.

The minutes of the four hundred and forty-eighth meeting were read and approved.

Mr. J. A. Ockerson reported that he had received a letter from the President of the Engineers' Club of Minneapolis stating that the Minneapolis Club had adopted a provision regarding the exchange of members among the Engineering Societies, similar to that in Section 8 of the by-laws of the Engineers' Club of St. Louis.

The paper of the evening by Mr. J. L. Van Ornum, entitled "Some Water Supplies of Southern California," was then read. The peculiar geographical and physical conditions of Southern California were briefly reviewed, and the methods of procuring water for irrigation and for the use of cities and towns were described. Although artesian wells and dams are often employed for the purpose of collecting water, the peculiarity of the region is the very extensive use of tunnels driven in the detritus, parallel to the course of the mountain streams. Numerous examples of the various methods were given.

After the reading of the paper, the meeting adjourned to another room, where refreshments were served.

RICHARD McCULLOCH, *Secretary.*

Technical Society of the Pacific Coast.

SAN FRANCISCO, CAL., REGULAR MEETING, FEBRUARY 5, 1897.—Called to order at 8.30 P. M. by Past President George W. Dickie.

The minutes of the last regular meeting were read and approved.

The following were elected to membership:—

For members:—

R. F. Masson, electrical engineer, of San Francisco.

Herman Meyer, civil engineer, of San Francisco.

For Junior:—

Harry H. Hirst, civil engineer, of San Francisco.

Mr. George W. Dickie thereupon addressed the society on its present standing and future possibilities as follows:—

VALEDICTORY ADDRESS.

TECHNICAL SOCIETY, February 5, 1897.

After having served you for two years as president, I may be permitted, in vacating this chair, to address you briefly on the condition of our society, and what will be necessary on the part of its members in order that that condition may be improved and a more vigorous life be imparted to all its members.

Your new President will not be able to do any better than his predecessors unless all the members realize that it is their privilege to give as well as to get, and that if the transactions of this society are to be of any service to the various professions that we represent they must be enriched by the experience and labors of all its members.

There is no excuse whatever for the existence of this society except as an instrument of mutual help in our varied callings. In our society, as in a great many others of a like character, the majority of the members are content with merely keeping up their membership, because such membership is an evidence that their standing in their profession is recognized by others, and perhaps more prominent members, in that profession.

I am surprised, when reading the applications for membership in this society, to see how much in engineering and kindred branches of applied science these gentlemen have accomplished in the past, and am still more surprised that the society benefits so little by the addition to its ranks of men who have been in charge of great works, who have built railroads, bridges, tunnels, canals, explored territories, located mines, designed great engines and other machinery, drained cities and taxpayers, built water works, and watered stocks.

If the experiences as set forth in the applications for membership could only be applied in the production of papers for our meetings, the transactions of this society would be rich indeed.

In looking over our list of members, I am surprised that the Directors should have to discuss the means of procuring papers, when there should be several on hand at all times from which to select.

Gentlemen, the poverty of our transactions accounts for the poverty of our treasury.

If our published papers were of vital interest to the profession we rep-

resent, our people would be more ready to contribute in order to possess them. The transactions of our society ought to be richer in original work and methods than those of any other society in the United States, because our membership covers a larger field in variety of work than that of any other society. Our conditions demand original work, and more of it is done here than elsewhere.

The industrial and engineering problems that confront this community, and that must be solved before permanent prosperity will prevail, will give vast opportunities to men of enterprise and skill in the various professions, and the working out of these problems will be of great interest to the professions throughout the world.

The material development of this state has hitherto been of slow growth. The cause of this retardation is largely due to the fact that those who came here first did not come to develop any of the natural resources around them, but to pick up the valuable things they found lying loose and go off with them to some place where their possessions would give the possessor importance.

Only works of immediate utility have been projected, and those of the most temporary character; hence the civil engineer has not yet had his opportunity. That opportunity will come when our people as a whole realize that this state is theirs to improve and develop, and that their future depends entirely upon what they do with this heritage of theirs, and enact wise laws looking to the fostering of every enterprise and industry necessary to the development of our resources.

In this development our society can and ought to take a leading part. Its members are those who should point the way; their profession requires them to study the very problems that confront this community: How to construct roads throughout the state; how to utilize the water-power of our mountains; how to transmit the power when generated; irrigation and the problems that cluster around that great subject; industries that should by nature succeed in this state; transportation problems, both by sea and land; the exchange of products with other peoples.

These and other great problems are in the future for us. Are they to remain problems, or are they to be solved for the benefit of ourselves and posterity? is the question of the present.

Such societies as ours are the natural solvers of such problems. Legislators and capitalists get their inspiration from what we say and write about them. Our work must go before the law that makes possible and the capital that makes practicable great works of utility; and I very much fear that the barrenness of our statute-books of any law designed to assist the development of any industry is due to the fact that so little interest is manifested by practical men in anything outside of their own immediate interests.

I have thought lately that we might, on alternate meeting nights, adopt topical subjects from the great problems to be solved by this state, and thus get into our transactions our best thoughts and practical experience on these questions, thus giving a mental stimulus to members who do not attend the meetings that will incite them to the preparation of papers on the subjects with which their daily work brings them into contact.

I trust our new President and his Board of Directors will find a way to bring into line all the ability of this society, both resident and non-

resident, so that our society life may be a positive power in the upbuilding of the professions we represent and a great factor in the development of our state.

It is now my duty, and I can assure you it is to me a great pleasure, to introduce to you Mr. E. J. Molera, whom you have chosen as your next President.

Mr. Dickie introduced to the society Mr. E. J. Molera, the President-elect for the ensuing year, who thereupon took the chair.

Mr. G. W. Percy read the paper of the evening, entitled "Peculiarities of Construction in the Noted Mole Antonelliana of Turin," which was discussed by members present.

Mr. George F. Allardt spoke of the proposed amendment to the Licensed Surveyors' Act, quoting from the Senate bill at length, and finally offered the following resolution:—

Resolved, That the Technical Society of the Pacific Coast, after a careful examination of Senate Bill No. 417, concerning licensed land surveyors, introduced by Senator Gleaves, fully indorses the provisions of the bill, believing that its enactment will tend to elevate the standing of the surveying profession, and ensure to land-owners more reliable surveys and the perpetuation of such surveys by suitable and permanent monuments.

The resolution was passed by vote, and the Secretary instructed to send a copy of it to Senator Gleaves, at Sacramento.

Adjourned.

Otto von Geldern, *Secretary.*

Directors' Meeting, February 5, 1897, at 4 p.m., President Molera in the chair.

Present: Directors Barth, Henny, Falkenau, Jones, Schild, and Von Geldern.

President Molera spoke of the advisability of getting members to take out a life-membership in order to raise the financial standing of the society. This project was discussed by the board.

The President thereupon appointed the following committees from the directory:—

Executive Committee—G. W. Percy, chairman; Edw. C. Jones and D. C. Henny.

Finance Committee—W. F. C. Hasson, chairman; Hermann Barth and Louis Falkenau; and named Messrs. Jones and Henny on the Board of Management of the Association of Engineering Societies.

The necessity was suggested of making appropriate arangements with the members of the society to induce them to prepare papers beforehand, in order to be able to set dates for certain subjects in ample time, without having to search for a paper on short notice. It was thought expedient to prepare a circular letter to this effect and send it to all members.

An amendment to the Licensed Surveyors' Act was laid before the board and referred by the Directors to the regular meeting to be held in the evening.

The Treasurer was instructed to pay two months' rent of rooms, and, to the Association of Engineering Societies, one assessment, as soon as funds sufficient are available.

Adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of Minneapolis.

MINNEAPOLIS, Minn., February 23, 1897.—The Engineers' Club of Minneapolis met in the Council Committee Room, City Hall, at 8 P.M.

President Frank J. Llewellyn in the chair.

The minutes of the last meeting were read and approved.

The President announced as the Committee on New Membership: W. R. Hoag, A. B. Coe, and E. H. Loe.

The resignation of Venon M. Smith was read and referred to the President.

The Secretary read as the report of the committee: The Memorial to Congress relative to Bill H. R. 9492, and letters from Hon. L. Fletcher and Senator C. K. Davis acknowledging its receipt and agreeing that it was meritorious. The report was accepted and the committee discharged.

Proposed for membership: Ellis J. Wolf, by W. R. Hoag and F. J. Llewellyn; H. E. Smith, J. E. Carroll, by F. J. Llewellyn and W. R. Hoag

The President read a letter from Wm. de la Barre, stating that he would be glad to show the Club what work was being done on the new dam below the St. Anthony Falls at any time which would be convenient to the Club.

The arrangement of such a trip was referred to the President and Secretary, with the suggestion that some Saturday afternoon might bring out the largest attendance, and that it would be agreeable to extend an invitation to the St. Paul Association of Civil Engineers.

The President announced the subject of the evening, "Good Roads," that Mr. Charles A. Forbes had disappointed him unavoidably, and that A. B. Choat had promised to be present and report the action taken at the late L. A. W. Convention, but was not here.

W. R. Hoag then read a paper on "Drainage of Country Roads," by E. A. Whitman, a student of the U. of M., followed by his paper on "European Roads," illustrated by numerous maps.

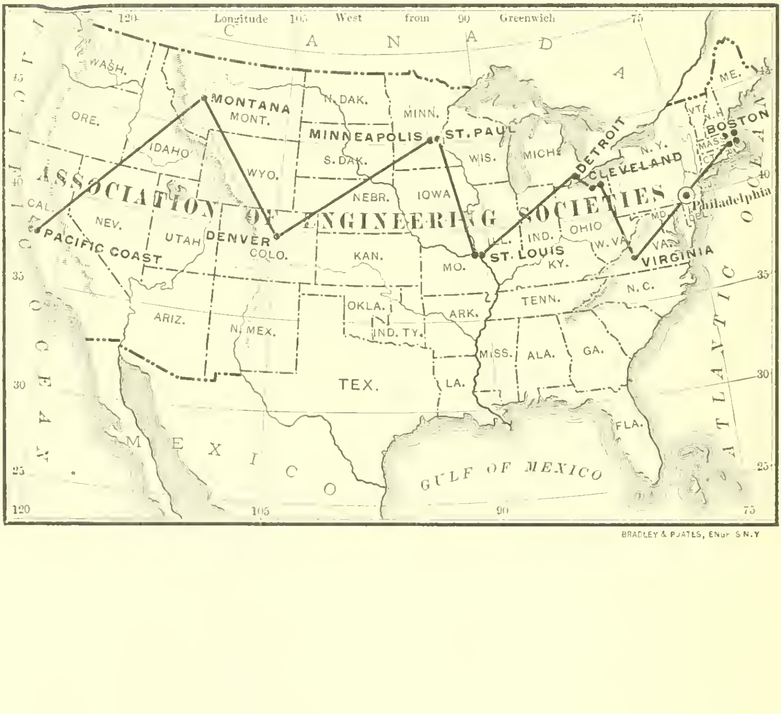
A motion that he put his papers and E. A. Whitman's in shape for publication in the JOURNAL carried.

In response to a request by the President, W. R. Hoag made a statement of proposed state legislation on road improvement.

A committee, composed of W. R. Hoag, F. W. Cappelen, and I. E. Howe, to draft and present a memorial favorable to the Constitutional Amendment and the Temporary Commission bills, was appointed.

Adjourned.

ELBERT NEXSEN, *Secretary*



BRADLEY & POATES, ENGR'S N.Y.

Association
of
Engineering Societies.

Vol. XVIII. **March, 1897.** No. 3.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Annual meeting of the Civil Engineers' Club of Cleveland, March 9, 1897. President Howe in the chair. Present, fifty members and five visitors. The minutes of the last regular meeting and of the semi-monthly meeting held February 23, were read and approved.

Messrs. Nelson and Hayes were appointed tellers to canvass the ballots for new members, and Messrs. Green and Ives to canvass the ballots for officers.

The application of Mr. Robert R. Muir for admission to active membership, and of Albert C. Bishop for admission to associate membership were read.

The Secretary reported the acceptance by the Executive Board of the resignation of Mr. G. H. Wadsworth, and of the promotion of John M. Wilson to the position of chief of engineers, U. S. A., with the rank of brigadier-general.

Mention was made of the receipt of a biographical sketch of Mr. J. F. Holloway, read by James F. Lewis before the American Institute of Mining Engineers.

The following resolutions were introduced by Mr. Searles, and seconded by Mr. Culley:

Resolved,—1. That the custom of providing light luncheons at the close of club meetings is an excellent one, promotive of mutual acquaintance, sociability and harmony, and should be continued.

2. That the expense of said luncheons is not a proper charge upon the treasury of the club, but like that of the annual banquet, picnic, and similar gatherings of a social nature should be met entirely by private subscription.

3. That, while approving the appropriation of funds already made by the board in testing the practicability and popularity of the lunch system, it is the sense of this meeting that such appropriations should cease for the future.

4. That a standing committee of three to be known as the Social Committee, with the Secretary as chairman, be appointed by the President to receive subscriptions and contributions to the Social Fund, to have the

custody of the same, distinct and separate from the funds in the treasury, to have the ordering of luncheons for the club at its discretion, and to pay for the same out of the Social Fund.

5 That said Social Committee be instructed to keep an accurate itemized account of receipts and expenditures, which shall be submitted to the President for approval prior to the annual meeting, and at any other time upon demand; and to report to the annual meeting only the *total* receipts and disbursements of the fund, and the balance remaining; which balance shall be turned over to the succeeding Social Committee.

6. That all members of the club are equally welcome and entitled to attend the luncheons of the club, as heretofore, regardless of subscriptions, and to invite non-members to accompany them at their discretion.

7. That these resolutions go into effect immediately.

After considerable discussion, the resolutions were laid on the table for one month.

The report of the Treasurer and the Finance Committee was then read by the chairman of the Finance Committee, as follows:

TREASURER'S REPORT.

CLEVELAND, O., MARCH 5, 1897.

Mr. President, and Members of the Civil Engineers' Club:—

GENTLEMEN:—I herewith submit the report of the Treasurer for the year starting March 10, 1896, and ending March 5, 1897. There was a balance left from last year of $181.83. There has been collected during the year: dues, $1,508.62; percentage on the Cleveland Frog and Crossing Company's advertisement in the Association of Engineering Society's journal, $72.00; balance returned by the JOURNAL, from extra assessment, $4.00, leaving a total for the year of $1,766.45.

The disbursements for this period have been, rent to Case Library, $112.50; one hundred and fifty-three membership tickets at $1.00 each, in Case Library, $153; Association of Engineering Societies, $381.75; this is the second, third and fourth quarterly assessment for 1896. Invoice of caterers for lunches after meetings, $181.38; stationery, printing, stamps, etc., $572.16; which makes a total of $1,400.79. This amount deducted from the receipts of $1,766.45, leaves a balance in the treasury of $365.66.

The permanent fund deposit with the Society for Savings last year was $417.70, to which has been added for the current year the sum of $115.00, from entrance fees, and $18.15 from interest, making a total of $133.15 that has been collected to the credit of the permanent fund this year. That added to the balance of last year of $417.70, leaves a balance of $550.85 for the permanent fund.

There has been collected for the library fund the sum of $215; there has been expended $197.02, which leaves a balance in the treasury of $17.98, to the credit of the library fund.

Respectfully submitted,

JAS. C. WALLACE, *Treasurer.*

Audited by James Ritchie, chairman; F. A. Coburn, members of the Finance Committee..

The report was received and ordered spread upon the minutes.

The Secretary's report was read as follows:

SECRETARY'S REPORT.

Mr. President, and Members of the Civil Engineers' Club:—

There have been added this year thirty-seven new members to the rolls of the club. The total number is now 191, of which 5 are honorary members, 15 are corresponding members, 21 are associate members, and 150 are active members.

The number of honorary members is the same as last year. The number of corresponding members is one more that last year. The number of associate members is eight more than last year. The number of active members is 19 more than last year. The total gain in membership is 28 members.

We have lost by death two members, by resignation six, and one member has been dropped for the non-payment of dues.

The total loss is nine members, making the net gain twenty-eight members.

We have made up the loss of the two previous years and resumed our old normal condition of increase.

The picnic which took the place of our August meeting was held at White's Villa in Rockport, a most beautiful place for that purpose. It was a great success, notwithstanding that most of us waited there one car too late and were somewhat wet by a summer shower.

One of the elements of the good time lay in our combining with the Architectural Club, which not only helped by increasing the number of the pleasant company, but also by enabling the committee to clear expenses. It is to be hoped that this union may be again effected this coming year.

When the first half of the year ninety-six was passed we had hopes that the year would see no one added to the ranks of those who have gone to represent us on the other side. But it could not be. Dr. C. O. Arey died on the 12th of August. At the meeting in June he read an interesting and scientific paper upon water supply and sewerage, and we little thought as we listened that it was the last time we should hear his voice, or that he, with so promising a work before him, would be thus cut off in the very prime of life.

At the July meeting we were entertained with a description of the great Bethlehem Iron Works.

Mr. Holloway inspired by a portrait shown upon the screen followed in an enthusiastic tribute to the worth and character of Mr. John Fritz, the founder of the works. There again, though we little thought it, we were listening to one of our oldest and dearest members for the last time in this life. Mr. Holloway died September 1. A large delegation from our club assembled at the funeral at Cuyahoga Falls. There we met Mr. Fritz, come upon the same sad errand as ourselves to pay respect to the memory of this great, good friend.

The attendance has been the largest of any year since our organization, the average number being 55.5-16. It is to be hoped that the attendance will continue, and that by the aid of this active working membership, and also of the interested visitors from whom we recruit our ranks, that the healthy growth of the club will be assured.

The exact percentage of visitors for the year can not be given, as the attempt to keep an account has been made but for a few months. For the last seven months it has been about 30 per cent. of the total.

During the year an attack has been made upon a small mountain of old papers of various descriptions, an accumulation since the birth of the club. The collection has been overhauled and everything of any possible value has been assorted and filed. The roll of all persons who have ever been members of the club has been corrected, and all are either now members or accounted for, and their records completed as far as available data could be obtained.

The Secretary is very grateful for the patience and charity with which the club has excused or overlooked his many failures and shortcomings. He has learned a great deal in many ways, and above all he has learned more to respect and love his brother-members. It only remains for him to say that the increase in interest, in attendance and in membership assures us that the angel of prosperity is with our Club.

Very respectfully submitted,

F. A. Coburn, *Secretary.*

March 9, 1897.

The report was received and ordered spread upon the minutes.

The report of the Librarian was read as follows:

LIBRARIAN'S REPORT.

To The Civil Engineers' Club of Cleveland:—

Gentlemen:—The following statement is submitted as the annual report of your Librarian: In addition to various government, state, and city reports and other bulletins and pamphlets, the club has received regularly about twenty different scientific periodicals, and undoubtedly many of the members have had occasion to appreciate the kindness of the publishers for these gratuitous contributions.

During the year 1896 nine papers, out of a total of forty-three by all members of the association, were published by this club in the Journal of the Association of Engineering Societies. This record does not vary greatly from that of the year 1894, when eight papers out of a total of thirty-four were contributed, but is a decided improvement over the year 1895, when but four papers out of a total of fifty-nine were credited to this club. The number of pages of reading matter in the Journal was increased from 717 in 1894 to 840 in 1895, but dropped to 499 in 1896. This falling off was due partly to the withdrawal of the Western Society of Engineers, and partly to the comparatively small number of papers offered by the societies of Boston and Virginia, who were liberal contributors the previous year. The Journal was started nearly twenty years ago through the efforts of this club, and by the earnest co-operation of the other societies of the association has long since proved its claim to a high position among the engineering publications of the United States. It is the duty of the club to see that this position is maintained, and it is earnestly hoped that the individual members will co-operate to this commendable end.

Great credit is due to the Program Committee for its systematic and able work during the past year, both for the many interesting meetings provided, and for the contributions to our publication. It is hoped that the new committee will profit by the excellent example set, and that it will do its best to improve upon the record made. Before leaving this subject your Librarian wishes to suggest that as far as possible all papers for publication be type-written and carefully corrected before handing in.

As a result of the establishment of the Library Fund through the suggestion and efforts of Mr. Culley, the amount of $210 was collected by the Library Committee the first year. Of this sum $197.02 was expended, and seventy-six books and nine numbers of the transactions of the American Society of Civil Engineers were bought for the club. While by its agreement the Case Library is called upon to expend an equal amount, it paid out the sum of $342.02 in the purchase of fifty-four books, and estimates the purchase of periodicals and binding at about $350.

A statement in regard to the approximate number of books and amount expended for the different branches of engineering may be of interest, and is as follows:

Civil Engineering (including surveying, sewerage, paving, and water works) 38 books at a cost of about $80.

Mechanical Engineering, 30 books at a cost of about $70.

Bridge Engineering, 7 books at a cost of about $21.

Electrical Engineering, 18 books at a cost of about $30.

Architecture, 14 books at a cost of about $230.

Marine Engineering, 9 books at a cost of about $30.

Chemistry (including mining and metallurgy), 5 books at a cost of about $8.

The necessity of a Library Committee composed of one representative from each of the branches of engineering, whose duty it shall be to pass upon the list of books to be purchased, and to keep the number and amount of money expended as nearly as possible proportional to the number of members of the different classes is apparent.

Perhaps the most important item of this report is one of news to the members. The club has received through our Past President, Mr. Mordecai, a donation of books from Miss Ellen Cleemann, as a memorial of the work of her brother, Mr. Thomas M. Cleemann.

The list includes:

Van Nostrand's Magazine from 1869 to 1886.

Engineering from 1867 to 1884.

American Engineer and Railroad Journal from 1887 to 1894.

Journal of the Association of Engineering Societies from 1881 to 1893.

Transactions of the American Society of Civil Engineers from 1872 to 1893.

Proceedings of the American Society of Civil Engineers from 1872 to 1882.

Proceedings of the Engineers' Club of Philadelphia from 1880 to 1893.

Poor's Manual from 1878 to 1882.

Annual Reports of the Water Department of Philadelphia from 1879 to 1891 (1883 and 1887 missing).

Pennsylvania Railroad Reports from 1863 to 1878.

Auditor General's Report of Railroads and Canals from 1866 to 1870.

Railroad Engineer's Practice by Thomas M. Cleemann.

By reason of Miss Cleemann's handsome donation the club's file of the transactions of the American Society of Civil Engineers is made complete.

In conclusion your Librarian desires to urge once more the earnest co-operation of each and every member in the effort to establish a complete scientific library in Cleveland. The fund is open for any and all contributions, and the club will welcome the gift of any scientific books which

can be spared by the members from their private shelves. The Librarian will be glad to receive suggestions and names of desirable books.

Respectfully submitted,

A. Lincoln Hyde, *Librarian.*

It was received and ordered spread upon the minutes of the club.

The following was offered by the Librarian:

Resolved, That the thanks of the Civil Engineers' Club of Cleveland be extended to Miss Cleemann for her very generous gift of books. That they be received and placed upon our shelves as a memorial of the work of her brother, Mr. Thomas M. Cleemann, well known as an accomplished and skillful engineer and writer.

It was adopted and the Librarian was directed to communicate with Miss Cleeman in accordance with the provision of the resolution.

The report of the Program Committee was then presented as follows:

REPORT OF THE PROGRAM COMMITTEE.

The Program Committee having completed its duties for the year has the honor to submit the following report:

Upon organizing, the policy of the preceding committee was adopted, viz.: that of filling at once all the list of meetings for the year with definite appointments as to lectures and topics. The result has proved so satisfactory that we confidently recommend the same policy to the consideration of the succeeding committee.

The Constitution only requires the committee to assign one of the general subjects and sub-divisions of engineering to each meeting, so that the whole field may be well covered in the course of the year; but the early announcement of a specific topic and the name of the speaker, lends additional interest to the work of the club, and the published calendar, like a handsome menu card, serves to prepare the membership for the feast of good things to come, and increases the zest with which it discusses them.

The number of papers secured for presentation to the club was so great that they could not be accommodated by the regular meetings only, and several semi-monthly meetings have been held in addition, which have been equally well attended, and have proved equally interesting with the others.

Indeed the absence of routine business gives the more time to the reading and discussion of the paper at the semi-monthly meeting.

The variety of topics considered during the past year illustrates the catholicity of the character as well as the title of the Civil Engineers' Club.

We have discussed the Smoke Nuisance and its Prevention under the joint leadership of Dr. C. F. Mabery and Professor C. H. Benjamin.

We have discussed Steam Engines as applied to direct connected Electric Generators, led by Mr. E. A. Sperry; the Phenomena of Electrical Discharges in Vacuo, a lecture by Dr. D. C. Miller, illustrated with apparatus; Water Supply and Sewerage as effected by the lower vegetable organism, with special reference to the health of the city of Cleveland; a very valuable paper presented by our late lamented member, Dr. C. O. Arey, only a few weeks prior to his death.

We had the pleasure of listening to a highly instructive lecture with elegant stereoptican illustrations on Modern Improvements in the art of Steel Forgings by Mr. H. F. J. Porter, of Chicago, by special invitation of the club.

The club discussed the subject of Solar Work in land surveying, and the new Solar attachment to the ordinary transit, the invention of our fellow-member, Mr. J. B. Davis, after listening to the paper of Mr. J. D. Varney.

Mr. Joseph W. Willard, associate member of the club, finished a comprehensive paper upon the History and Nature of Explosives, and by request supplemented this at a subsequent meeting by a paper on Modern Explosives. This was followed by a lecture from Dr. C. F. Mabery on the Chemistry of Explosives, and a general discussion by the members.

Mr. C. L. Saunders read a paper on Gas Producers and the Mechanical Handling of Fuel for the same. Mr. Jos. R. Oldham furnished a paper on the Structural Strength of Ships with special reference to the requirements of navigation on the Great Lakes, and another on Steamship Propulsion, and the relative resistance of deep and shallow draft vessels which was vigorously discussed.

Mr. Jas. Ritchie read a paper with blue-print illustration on some instances of Recent Roof Construction, which elicited discussion.

Mr. S. T. Dodd gave the club a graphic description with illustrations of the Niagara Falls Electric Power Plant, and of the immense industries of various kinds that have been recently established in that vicinity.

Professor C. H. Benjamin read a paper on the Use of Electric Motors on Machine Tools, showing the advantage in large plants, of local motors over long lines of shafting and belts, and Dr. Cady Staley addressed the club on the Sanitation of Paris, giving the history of its sewer system, and a description of its famous sewers, and of the broad irrigation system in operation at Gennevilliers.

The committee has also provided for the regular meeting in April next an illustrated lecture upon European Architecture by Dr. Cady Staley.

As generous as the foregoing list may appear, the sessions of the club were not numerous enough to receive all the papers proposed. No less than three are necessarily postponed to be enjoyed on some future occasion. These papers are by Messrs. Richardson, Short and Warner respectively.

A number of the foregoing papers have duly appeared in the JOURNAL of the association. It is to be regretted that a larger number were not presented in manuscript shape so as to be sent to the printer. It is also to be regretted that some of the discussions could not be preserved in print, since they contained information of great value and interest.

The club has reason to congratulate itself on the amount and quality of the scientific work it has accomplished during the past year, on the value of the papers read, and on the spirited and intelligent discussions that have ensued. These are the signs of a vigorous life, a useful career, and are the promise of a brilliant future. By this kind of work the club commends itself not only to the engineers of Cleveland, but to the intelligent community at large, which realizes that all advancement in public comfort, happiness and real prosperity has its origin in the brain of the patient thinker, the close student, and the industrious worker in the domain of science.

Respectfully submitted,

WM. H. SEARLES, *Chairman*, C. F. SCHULZ,
JOSEPH R. OLDHAM, JOHN G. OLIVER,
D. C. MILLER, F. S. BARNUM,
S. T. DODD,

Program Committee.

The report was received and ordered spread upon the minutes.

The retiring President then delivered his annual address, "The Early History of Instruments and the Art of Observing in Astronomy and Civil Engineering." (See address in the previous pages of this number of the JOURNAL.)

The announcement of the election of Dr. E. W. Morley as an honorary member of the club was announced, and was greeted with applause.

The President announced the election as active members of Lyman Marshall, Philip E. Knowlton, Wm. E. Reed, Chas. Goffing, Wm. B. Hanlon, John P. Johnson, Lewis C. McLouth, and Edward E. Rose, and as associate member of Wm. Oehlstrom.

The report of the tellers on election of new officers was read as follows:

President: James Ritchie.

Vice-President: C. M. Barber.

Secretary: F. A. Coburn.

Treasurer: Hiram Kimball.

Librarian: A. Lincoln Hyde.

First Director: John W. Langley.

Second Director: Wm. C. Jewett.

After a few remarks by President-elect Ritchie a resolution was offered by Mr. Searles thanking the retiring officers for their faithful and efficient services. It was unanimously adopted.

The meeting adjourned and a light lunch was served.

F. A. COBURN, *Secretary.*

Engineers' Club of St. Louis.

450TH MEETING, MARCH 3, 1897.—The meeting was called to order at 1600 Lucas Place, with President Flad in the chair, at 8 P. M. Thirty-three members and four visitors were present. The minutes of the four hundred and forty-ninth regular meeting and the two hundred and thirty-second meeting of the Executive Committee were read and approved.

The application for membership of Mr. William H. Reeves, manager of the St. Louis office of Henry R. Worthington, was announced and referred to the Executive Committee.

The Secretary read the correspondence which the club had received regarding its memorial to Congress relating to House bill No. 9492, concerning the appropriation for the improvement of the Lower Mississippi River.

The question of serving lunch at the meetings of the club was then taken up and discussed at length. On motion it was finally decided that the lunch should not be paid for out of the funds of the club. Several members then expressed a willingness to contribute to a special fund for this purpose.

The paper of the evening by Mr. Thomas B. McMath on "The Design of the Edgebrook Bridge" followed. The Edgebrook Bridge carries the tracks of the St. Louis and Meramec River Electric Railway over the Missouri Pacific tracks and River Des Peres at Edgebrook, St. Louis county, Mo. Its entire length is 900 feet, and it contains two spans of 135 feet each.

This bridge is typical of a new class, intermediate between the highway bridge and the steam railway bridge. The writer discussed the main points in the specifications, the principal features in the design, the loads for which the bridge was calculated, and the methods employed in letting the contract. After the reading of the paper a number of lantern slides showing views taken during the construction were exhibited. An interesting discussion followed, participated in by Messrs. Crosby, Barth, Ockerson and Borden.

Professor J. H. Kinealey then exhibited a glass model illustrating the working of the Pohle air lift pump. He showed the method of operating the pump and explained several theories in regard to its action. Following the discussion of this apparatus, the members adjourned to another room, where lunch was served.

RICHARD MCCULLOCH, *Secretary.*

451ST MEETING, MARCH 17, 1897.—The meeting was called to order at 8 P. M., with President Flad in the chair. Forty-three members and ten visitors were present. The minutes of the four hundred and fiftieth regular meeting and the two hundred and thirty-third meeting of the Executive Committee were read and approved.

The application for membership of Mr. William H. Reeves, manager of the St. Louis office of Henry R. Worthington, having been favorably reported by the Executive Committee, this gentleman was balloted for and elected a member of the club.

The Secretary read a letter from the Western Society of Engineers regarding the memorial to Congress concerning the improvement of the lower Mississippi River.

The paper of the evening by Mr. Julius Baier was then read. It was entitled "Wind Pressure in the St. Louis Tornado with Special Reference to High Building Construction." This paper was the result of a thorough study of the St. Louis tornado of May 27, 1896. From the known stability of a number of structures wrecked in the storm, the minimum force of the wind was estimated. The theory of tornadoes and a number of observations of tornado effects in other places were given. Instruments for measuring the speed and force of the wind were described, and their limitations defined. Experiments showing the relative pressure and suction action of the wind on various shapes were cited. A large number of lantern slides were exhibited showing views of other tornadoes and views taken after the St. Louis tornado. Following Mr. Baier, Dr. Frankenfield, of the United States Weather Bureau, made a few remarks.

The meeting then adjourned to another room, where lunch was served.

RICHARD MCCULLOCH, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., March 1, 1897.—The regular meeting of the Civil Engineers' Society of St. Paul was called to order at the usual hour by President Hilgard.

Fourteen members and five visitors present. Minutes of previous meeting read and approved. The favorable report of the Committee on Im-

provement of the Southwest Pass was accepted, and the Secretary was directed to send copy of same to the Engineers' Club of St. Louis.

The following standing committees were named by the President:

Bridges: A. W. Münster and Max Toltz.

Hydraulics: A. W. Münster and George L. Wilson.

Power Plants: A. O. Powell and O. L. Claussen.

Publication: C. L. Annan and E. E. Woodman.

The President suggested as a topic for the immediate consideration of the Committee on Bridges, the compatibility of beauty and strength in structural designs. The question of class membership was discussed, and the matter was turned over to Mr. Woodman, Mr. Crosby and Mr. W. L. Darling to formulate and present.

Mr. Crosby then read a short paper on a "Device for Raising Cars up the Selby Avenue Hill." He proposed to install, underground at the crest of the hill, an electric motor to run a cable trolley in a conduit from which a grappling apparatus should project upward through a slot. This was illustrated by a working model. The cost would be from $20,000 to $30,000, depending on the permanence of the work.

The substance of a note from Mr. Powell, received before adjournment, was laid before the meeting.

The sympathy of the members was tendered Mr. and Mrs. Archibald Johnson in their bereavement, and Mr. Powell was authorized to provide an appropriate floral expression.

C. L. Annan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, March 5, 1897.—Called to order by President Molera.

The minutes of the last regular meeting were read and approved.

The following gentlemen were elected to membership: G. A. Kornberg, mining engineer, of San Francisco; W. P. Moore, architect, of San Francisco; A. E. Brooks Ridley, electrical engineer, of San Francisco.

Application for membership of Edward J. Hewitt, instructor, of 619 Capp street, San Francisco, proposed by A. E. Chodzko; L. A. Buchanan and J. Richards, referred to the Board of Directors.

The President stated that a paper had been procured for the evening, but that the author had been obliged to leave town on business, and could not be here this evening to read his paper.

Mr. George W. Dickie spoke of the advisability of having topical questions prepared before hand, so that a subject might always be announced, when there is no set paper for the evening.

The following topical subjects were then listed as agreed upon by the society for the ensuing year:

1. Transmission of power in Manufacturing establishments.
2. What is the efficiency of large-sized centrifugal pumps?
3. The efficiency of water wheels.
4. Engineering instruments, modern types and their application to engineering field work.
5. Modern machine shop practice.

6. California building materials.
7. High-building construction in cities.
8. The California irrigation law and its practical operation.

Mr. C. E. Grunsky addressed the members informally on the subjects of the "Turlock and Modesto Irrigation District Dam and Canal."

Adjourned.

OTTO VON GELDERN, *Secretary.*

William Albert Allen.—A Memoir.

By H. BISSELL AND E. W. HOWE, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read January 27, 1897.]

William Albert Allen, the eldest son of Rev. Charles F. and Ruth S. Allen, was born at Bath, Me., October 18, 1852. He was a descendant, in the eighth generation, of George Allen, who was born in England in 1568, and came to New England in 1635. George Allen's grandson, James Allen, was one of the original proprietors of Martha's Vineyard, and five generations of the family lived on that island. Rev. Charles F. Allen, D.D., was the first president of the Maine State College, and for over fifty years was one of the leading clergymen of the Methodist Church in Maine.

Mr. Allen attended the public schools of Portland, Eaton School at Morridgewock, graduated from the Bangor High School, Kent's Hill Seminary, and from Maine State College, where in 1874 he received the degree of Civil Engineer. He soon after entered the service of the Maine Central Railroad, and in January, 1885, was appointed chief engineer, which position he held until his death, March 21, 1896, caused by falling from a train crossing the Androscoggin River while inspecting repairs which were being made to the piers of the bridge. He was also chief engineer of the Portland Union Railway Station Company from the commencement until the completion of the work. His wife, Ella, daughter of Samuel Rolfe, Esq., of Portland, Me., died in 1895. They had no children.

Mr. Allen was elected a member of the Boston Society of Civil Engineers April 15, 1885, and of the American Society of Civil Engineers May 6, 1891.

Mr. Allen's high natural abilities with his technical education made him a valuable man in his position. He won and held the respect and confidence of the officials and men on the road, and all others with whom he came in contact to an unusual degree. On the excursion of the American Society of Civil Engineers to the White Mountains in 1895, Mr. Allen, as representative of the M. C. R. R., looked after the interests and comfort of the party, contributing largely to the pleasure of the occasion, yet doing it all so quietly and modestly that probably many were unaware of his presence.

One of his associates says of him: "Beneath an unassuming and modest bearing, behind a quiet but genial manner lay a respect for duty, and a keen appreciation of the finer discriminations of business honesty extending to the minutest detail of every day life. His unselfish regard for

others, his constant care for the welfare of those about him were characteristics of which those with whom he came in contact were constantly reminded. In many ways not pertaining strictly to his own department of work, Mr. Allen by his tact, ready pen and sound judgment, rendered most valuable service to the Maine Central Railroad. For his true hearted and manly characteristics among men of affairs throughout the State of Maine, Mr. Allen was held in high esteem, and his sad death brings real sorrow to a wide circle of representative business men who had learned to regard him as one of the most conspicuous of the younger professional men of the State."

Boston Society of Civil Engineers.

February, 17, 1897.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock, p. m., President George F. Swain in the chair. Ninety-three members and visitors were present.

The record of the last meeting was read and approved.

Messrs. William G. S. Chamberlain, Joseph S. Craigue, Frederick H. Cunningham, Harry A. Frink, Herman K. Higgins, Frank P. McKibben, George M. Warren, and Charles E. Wells were elected members of the Society.

The thanks of the Society were voted to the general manager of the Atlantic Works, to the agent of the Furness Line of steamers, to Captain Knight, of the steamship "Borderer," and to the president of the Simpson Dry Dock Company, for courtesies shown the members who took part in the excursion this afternoon.

Mr. Woods brought to the attention of the Society the recent action of the Civil Service Commission in placing municipal engineers under civil service rules, and on motion of Mr. Fitzgerald it was voted that a committee of three be appointed by the President to ascertain and consider the facts in regard to the proposed civil service rules as applied to municipal engineers, and report what action, if any, it is advisable for the Society to take.

The President appointed as members of that committee, Henry Manley, chairman; Frederic P. Stearns and Frederick Brooks.

Mr. Charles W. Sherman then read the first paper of the evening, entitled "The 100-foot Standard of Length at Chestnut Hill Reservoir."

The paper was illustrated by lantern slides, and was discussed by Messrs. Burton, Fitzgerald and Foss.

The second paper was by Mr. R. S. Hale, on "European Boiler Practice," and was very fully illustrated by lantern slides. It was discussed by Mr. Charles T. Main and Professor I. N. Hollis, and in a communication from Mr. George H. Barrus, which was read by the Secretary.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston Society of Civil Engineers.

Annual Meeting, March 17, 1897.—The annual meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, Boston, at 7.55 o'clock p.m. President George F. Swain in the chair. Eighty-three members and visitors present.

The record of the last meeting was read and approved.

Messrs. Irving T. Farnham, Frederic H. Fay, Clifford Foss, Leonard Metcalf, William Nelson, Nathan R. Pratt, and William E. Stark were elected members of the Society.

The annual report of the Board of Government was read by the Secretary, accepted, and placed on file.

The annual reports of the Treasurer and the Secretary were also read, accepted, and placed on file.

Prof. Porter, for the Committee on Weights and Measures, presented the report of that committee, which was accepted and placed on file.

The report of the Committee on Excursions was presented by Mr. Knowles, and was accepted and placed on file.

Mr. Doane made a brief report for the Committee on Quarters, which was accepted.

The Librarian read the annual report of the Committee on the Library, and supplemented it with a very interesting acount of the catalogue system used in the library. The reports were accepted and placed on file.

On motion of Mr. Manley, the thanks of the Society were voted to the retiring Librarian, Mr. Alfred D. Flinn, for his arduous and painstaking labors in the interest of the Society during the past year.

It was also voted that the question of printing the reports of the several committees be referred to the Board of Government with full power.

In accordance with the recommendation in the report of the Committee on the Library, the sum of $50 was appropriated for binding and other library purposes.

On motion of Mr. Rice, the Board of Government was authorized to expend a sum not exceeding $100 for the preparation of a card subject index of the municipal, state, and government reports in the library.

The committee appointed at the last meeting to "consider the facts in regard to the proposed civil service rules as applied to municipal engineers" submitted the following report, which was accepted and the recommendation adopted.

The committee appointed "to ascertain and consider the facts in regard to the proposed civil service rules as applied to municipal engineers and to report at a future meeting what action, if any, is desirable for the Society to take," have attended to that duty and report as follows:

The Civil Service Commissioners of Massachusetts have adopted rules including within the classified civil service of the State, "civil engineers, draughtsmen, transitmen, levelers, chainmen, rodmen, and all assistants under whatever designation except laborers, employed in any city of the Commonwealth or in any town, accepting the provisions of Chapter 267, of the Acts of 1894," which action was confirmed by the Governor and Council on December 3, 1896, and said rules went into effect on February 15, 1897.

The municipalities affected by this action at this time include all the cities of the State and the town of Brookline.

The Commissioners have not yet formulated any classification of engineers beyond that stated in the rules above quoted, no examinations have yet been held, and the detailed arrangements for such examinations have not yet been concluded.

Your committee have the assurance of the Commission that the aid of the Society in completing the arrangements for carrying the rules into effect will be welcomed by them, and believing that the Society can thereby be of service to its members, unanimously recommends that a standing committee to consist of five members be appointed by the Board of Government, to be called the Committee on Municipal Civil Service, with authority to represent the Society in all matters affecting the interests of its members in connection with the classified municipal civil service in the Commonwealth of Massachusetts.

Henry Manley,
Frederic P. Stearns,
Fred. Brooks.

Mr. Stearns moved to refer to the Board of Government, with full powers, the question of continuing the several special committees of the Society and the selection of the members thereof. Mr. A. H. Howland opposed at considerable length the continuation of the Committee on Weights and Measures and criticised severely its work during the past year. The motion of Mr. Stearns was, however, adopted.

Mr. James Francis, in a short and reminiscent address, presented to the Society an excellent crayon portrait of his father, the late James B. Francis, fourth President of the Society. President Swain, in a few appropriate remarks, accepted the gift, and on motion of Mr. Doane, the thanks of the Society were voted to Mr. Francis for his valued gift.

Messrs. F. O. Whitney and H. B. Wood, the tellers of the election, submitted the result of the letter-ballot for officers. There being no election for Vice-President and Director by letter-ballot, the meeting proceeded to choose these officers from the two candidates for each office having the highest number of letter-ballots.

The President announced, as the result of the balloting, the election of the following officers:

President—Dexter Brackett.

Vice-President (for two years)—C. Frank Allen.

Secretary—S. Everett Tinkham.

Treasurer—Edward W. Howe.

Librarian—William B. Fuller.

Director (for two years)—Dwight Porter.

President George F. Swain then delivered the address of the retiring President.

Adjourned.

S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1896-97.

To the Members of the Boston Society of Civil Engineers:—

In compliance with the provisions of the Constitution, the Board of Government submits the report for the year ending March 17, 1897.

Ten regular meetings and one special meeting have been held during the year, and the fifteenth annual dinner of the Society was given at the Hotel Brunswick on March 9, 1897. The aggregate attendance of members and visitors at the regular and special meetings was 1,474, an average of 134, the smallest being 42 and the largest 318. The number present at the annual dinner was 150.

The following papers and lectures have been read at the several meetings:

March, 1896.—Address of President Albert F. Noyes. "Preservation of the Bulfinch Front of Massachusetts State House," by H. A. Phillips.

April, 1896.—"Riveted Joints," by J. R. Worcester.

May, 1896.—"One Month in Aztec Land," by Fred. Vincent Fuller (illustrated).

June, 1896.—"History of Stone Bridges," by President Geo. F. Swain (illustrated).

September, 1896.—"Recent Practice in Railroad Signalling," by Geo. W. Blodgett.

October, 1896.—"Brief Account of Topographical Work on Mr. Geo. W. Vanderbilt's North Carolina Estate," by John L. Howard. "Topographical Surveys of the Metropolitan Park Reservations of Massachusetts," by Henry F. Bryant. "Memoir of James H. Stanwood."

November, 1896.—"The Tampico Harbor Works, Mexico," by E. L. Corthell (illustrated).

December, 1896.—"Sewer Assessments," by F. Herbert Snow. "Memoir of Forrest L. Libbey."

January, 1897 (special).—"An Account of Last Summer's Expedition to Umanak Fjord, West Greenland," by Prof. Alfred E. Burton (illustrated).

January, 1897.—"Various Inventions and Devices for Building Tunnels and Passageways under Rivers and Other Bodies of Water," by H. A. Carson (illustrated). "Memoirs of William A. Allen and Albert F. Noyes."

February, 1897.—"The 100-ft. Standard of Length at Chestnut Hill Reservoir," by Charles W. Sherman (illustrated). "European Boiler Practices," by R. S. Hale (illustrated).

At the annual meeting a year ago, the total membership of the Society was 389, of which 381 were members, 4 honorary members, and 4 associates.

During the past year we have lost 12 members; 4 by death, 1 by resignation, and 7 by forfeiture for non-payment of dues.

There have been added to the Society during the year 59 members; 56 members have been elected by the Society, and 3 former members have been reinstated by the Board of Government. Two others have been elected, but have not as yet accepted membership. Our present membership consists of 5 honorary members, 4 associates, and 427 members; a total of 436, an increase for the year of 47. Past President George L. Vose has been made an honorary member.

The record of deaths for the year is as follows:

William A. Allen, died March 21, 1896.
Waterman Stone, died March 30, 1896.
James H. Stanwood, died May 24, 1896.
Albert F. Noyes, died October 12, 1896.

The informal meetings of the Society have been continued during the year. The attendance at several of these meetings held this winter in the new library has been fully equal to the capacity of the room.

The subjects discussed have been as follows:

March 25, 1896.—"Topographical and Other Work on the Vanderbilt Estate at Biltmore, N. C.," by J. L. Howard.

April 1, 1896.—"Construction of Water Street Sewer, Lawrence," by A. D. Marble.

December 1, 1896.—"Boston Subway," by H. A. Carson.

December 9, 1896.—"Civil Engineering Work of the West End Street Railway, Boston," by A. L. Plimpton.

December 30, 1896.—Some Problems in Railroad Signalling and Electric Locking," by George W. Blodgett.

January 6, 1897.—"Some Details of Street Construction in Boston," by Henry Manley.

February 3, 1897.—"Metropolitan Water Supply," by F. P. Stearns.

February 10, 1897.—"Railroad Stations," by J. P. Snow.

February 24, 1897.—"Sewage Disposal," by Allen Hazen.

March 3, 1897.—"High-Service Water Supply, Lawrence," by A. D. Marble.

At the time of the last annual report, we were preparing to take possession of our new quarters, with which you are now so familiar. The first meeting in Tremont Temple was held May 20, 1896, and we are now provided with commodious and convenient quarters for our library, as well as with a proper hall for our meetings. The fitting and furnishing of the new rooms were paid for by means of a subscription amounting to $821, which was received from members of the Society. The thanks of the Society are due to the committee that so efficiently superintended the work of furnishing.

The acknowledgments of the Society, as well as of the Board of Government, are due to the retiring Librarian, Mr. Alfred D. Flinn, who has given a great deal of time during the last year to the work of arranging and marking the books and preparing a card catalogue of them. The details with regard to this work are given in his report. Our library is now more available and in better working condition than it has ever been before.

The Society has lost some valued members by death during the past year. The most prominent among these was our beloved ex-President, Albert F. Noyes, whose influence in the Society was always for good, and whose cheerful spirit and willing hand will long be missed. The Board of Government desires to place on record here its sense of the deep loss which the Society has sustained, and of its respect, admiration, and love for him who has gone before. At one of the recent meetings of the Society, an excellent picture of Mr. Noyes was presented to the Society by a number of our members, the speech of presentation being made by Mr. FitzGerald. This picture now hangs with those of other deceased presidents in the rooms of the Society, and we are sure that the memory of the original will long be kept green among us.

During the past year the annual dues of the Society have been increased from $7 to $8, for residents, and $4 to $5, for non-residents. This

increase will provide a welcome addition to the funds of the Society, and will enable us to meet our increasing expenses, and at the same time add to the interest of our meetings and convenience of our quarters. The Board of Government congratulates the Society on the completion of another prosperous year.

Respectfully submitted for the Board of Government.

GEO. F. SWAIN, *President.*

ABSTRACT OF THE TREASURER'S AND SECRETARY'S REPORTS FOR THE YEAR 1896-97.

CURRENT FUND.

Receipts:		
Dues from new members	$317.00	
Dues for year 1896-97	2,730.00	
Dues for year 1895-96	7.00	
Dues for year 1897-98	18.00	
Dues for year 1887-88	6.00	
Rent of rooms	687.50	
Sale of old book cases	25.37	
Return premium on insurance	4.78	
Fines on books in library	.19	
Cash at beginning of year	96.76	
		$3,892.60
Expenditures:		
Rent	$1,552.55	
Association of Engineering Societies	1,250.25	
Printing and postage	278.10	
Secretary's salary	200.00	
Annual dinners of 1896 and 1897	175.20	
Periodicals and binding	151.30	
Incidentals	86.92	
Stereopticon	66.55	
Lighting rooms	25.62	
Cash on hand	106.11	
		$3,892.60

PERMANENT FUND.

Receipts:		
Fifty-six entrance fees	$560.00	
Shares of Merchants Co-operative Bank, retired	227.18	
Subscription to Building Fund	50.00	
Interest and dividends	135.96	
On hand at beginning of year	2,099.56	
		$3,072.70
Expenditures:		
Deposit in Provident Institution for Savings	$1,025.15	
Deposit in Boston 5c. Savings Bank	1,010.00	
Dues on shares in Merchants Co-operative Bank	308.00	
Dues on shares in Workingmen's Co-operative Bank	300.00	
Dues on shares in Volunteer Co-operative Bank	300.00	
Cash on hand uninvested	129.55	
		$3,072.70

FUND FOR FURNISHING ROOMS.

On hand at beginning of year	$300.00	
Received from subscriptions	521.00	
		$821.00
Expended for furnishing rooms		$821.00

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 17, 1897:

One Republican Valley Railroad bond (par value)	$600.00
9 shares C., B. and Q. R. R. stock (par value)	900.00
25 shares in Merchants' Co-operative Bank	2,806.18
25 shares in Workingmen's Co-operative Bank	581.50
25 shares in Volunteer Co-operative Bank	547.00
Deposit in Provident Institution for Savings	1,025.15
Deposit in Boston 5c. Savings Bank	1,010.00
Cash on hand	129.55
	$7,599.38
Amount belonging to permanent fund March 18, 1896	$6,640.21
Increase during the year	$959.17

Report of Committee on Excursions.

Boston, March 17, 1897.

To the Members of the Boston Society of Civil Engineers:—

The Society has made the following excursions during the past year:

April 15, 1896.—Quincy Market Cold Storage; attendance, 30.

May 20, 1896.—Boston Subway; attendance, 75.

June 17, 1896.—Dam and Basin V, Metropolitan Water Works, Southboro; attendance, 35.

September 16, 1896.—Elevating Tracks, Providence Div. N. Y., N. H. and H. R. R.; attendance, 35.

November 18, 1896.—Works of the Geo. F. Blake Mfg. Co.; attendance, 4.

December 30, 1896.—Railroad Terminals and other works at Providence, R. I.; attendance, 75.

January 27, 1897.—Boston Subway; attendance, 500.

February 17, 1897.—Atlantic Works and Simpson Dry-dock; attendance, 35.

March 17, 1897.—Grade Crossing Work at Newton; attendance, 50.

Average attendance, 93. But leaving out the visit to the Blake Pump Works, which was unusually small, and that to the Subway, which was unusually large, the average attendance was 48.

The committee beg leave to offer the suggestion that it is not wise to attempt to provide an excursion for every meeting of the Society. There have been so many excursions in times past that it now becomes a difficult matter to arrange an excursion which will be of general interest without going to inconvenient distances. This committee has followed what seemed to be the precedent of trying to provide an excursion for each meeting, but think that next year's committee should be given to understand that this is not expected of them, and that if an excursion cannot be

planned to some point or work of general interest, they should feel at liberty to omit it for that meeting.

It is embarrassing to the committee, unjust to the parties whom we propose to visit and who may take considerable pains to entertain us, and we think not very creditable to the Society, to have but a very small number respond. Therefore the committee is of the opinion that it would be better policy to arrange fewer excursions and those to points of general interest where the committee may be sure of a large attendance.

For the committee.

E. S. DORR, *Chairman.*

REPORT OF COMMITTEE ON WEIGHTS AND MEASURES.

MARCH 17, 1897.

To the Boston Society of Civil Engineers:—

Gentlemen:—Your Committee on Weights and Measures has not been called upon for any specific action during the year, but begs to present some further statements in the line of its report of a year ago. At that time a bill was before Congress (H. R. 2758), which had been introduced in the House by Mr. Hurley in December, 1895, and which provided that from July 1, 1897, the metric system only should be used by all departments of the Government, and from July 1, 1899, it should be the only legal system of weights and measures recognized in the United States.

This bill was considered in the Committee on Coinage, Weights and Measures, and a substitute bill (H. R. 7251, Report No. 795) was unanimously reported to the House March 16, 1896. This bill excepted the public land surveys from its provisions and made the date for the adoption of the metric system by Government Departments July 1, 1898, and for its legal recognition throughout the United States January 1, 1901.

In April a motion to order this bill to engrossment and a third reading was successfully opposed in the House and failed by a vote of 65 to 80.

The bill was re-committed to the Committee on Coinage, Weights, and Measures, which on February 10, 1897, reported it back again, amended so as to extend the date for the adoption of the system in Government Departments to July 1, 1900, and for general recognition to January 1, 1903. The bill and accompanying report were referred to the House Calendar, which statement brings the history of this measure down to the present time.

This bill does not at all propose to make the use of the metric system compulsory on the part of the people, but only to establish it as a legal standard to which reference can be made in case of dispute, or for any other proper purpose. The proposed action is similar to that of the Government when it established a legal system of coin and currency denominations, the use of which it actually forced upon no one.

In its report the Committee on Coinage, Weights, and Measures stated that petitions favoring the passage of the bill had been received from all parts of the country and from men in all vocations. Among these were represented the Engineers' Club of Philadelphia, the Association of American Steel Manufacturers, the faculties of twenty-seven colleges in sixteen different States, and various State educational associations.

It should be said that the action of the Engineers' Club of Philadelphia

in favoring the bill was taken only after a lively discussion and a letter ballot, the latter resulting in a vote of 100 for, and 60 against, the approval of the bill by the Club.

In January, 1897, the Illinois Society of Engineers and Surveyors, at its annual convention, endorsed the adoption of the metric system.

On the other hand, the Master Mechanics and Car Builders' Associations, at their meetings in June, 1896, adopted resolutions protesting against the bill then before Congress.

Abroad, England and Russia are substantially the only prominent nations which are non-metric, and it is evident that in England the metric system is rapidly gaining in favor. The New Decimal Association of England publishes a list of organizations which have formally approved that system, including twenty-nine town councils, eighteen trades councils, twenty-nine town school boards, thirty-nine chambers of commerce (including those of London, Liverpool, Birmingham, Sheffield, etc.), and between forty and fifty other associations, thoroughly representative in character and largely including in their membership retailers, who might be supposed to be especially affected by the change of standards.

Your committee has no recommendation to make calling for formal action on the part of this Society with reference to the metric system, but would urge upon the members individually a careful consideration of this question in its present stage. It would call attention to the opinion expressed by the late President Roberts, of the Pennsylvania Railroad, who, in favoring the bill to which reference has here been made, said: "I am heartily in accord with the efforts to establish a metric system of weights and measures for our country. It is only a want of knowledge on the part of the general public of what the adoption of such a system means, in simplifying everything that depends upon weights and measures in our country, that I am sure prevents the measure being more heartily seconded by the public. After it is once adopted it would be ten times more difficult to get the public to return to the present system than it is at present to get them to change to the metric."

Respectfully submitted,

Chas. T. Main,
Allen Hazen,
Dwight Porter,
Committee on Weights and Measures.

MONTANA SOCIETY OF ENGINEERS.

A special meeting of the society was held in its rooms, in the Merchants' National Bank Building, Helena, March 29, 1897. Meeting called to order at 8 p.m., Vice-President A. E. Cumming in the chair. There was a large attendance of members, county surveyors, and guests. Among the latter were several members of the last Legislative Assembly. The minutes of the last meeting were read and approved. The applicants for membership were Benjamin Bond, Donald Bradford, and E. M. Wardwell. The Secretary stated that the Helena Free Public Library and the Butte Free Public Library had been placed upon the mailing list for the Journal

of the Association of Engineering Societies, with back numbers from the middle of the year of 1888; that the society desired to place the Journal in other important public libraries in the State, and the Secretary was instructed to send notice to members that all those who wished to contribute Journals for this purpose, to please send the same to him to be distributed. A vote of thanks was tendered Hon. G. A. Bruffy and other members of the Fifth Legislative Assembly of the State of Montana, who were instrumental in procuring the passage of the new road law, and to Hon. Lee Word, attorney-at-law, who spent much time in framing the bill. Much discussion ensued upon the County Surveyors' Convention, which was to meet on the following day. A paper was received from M. S. Parker, of Great Falls, to be read before the convention. Hon. Lewis Penwell, of the last Legislative Assembly, was appointed a committee of one to prepare an opinion upon the road law to present at the convention. The new road law, which is materially different from any other road law in the United States, inasmuch as it places the construction and maintenance of roads and bridges entirely under the supervision of county surveyors, was then read and thoroughly discussed. The introduction of this law was largely through the instrumentality of the Montana Society of Engineers, and is as follows:—

An Act to Define the Powers and Duties of County Surveyors, and to Provide for their Compensation, and to Abolish the Office of Road Supervisor.

Be it enacted by the Legislative Assembly of the State of Montana:—

Section 1. It shall be the duty of the County Surveyor of each county of the State to divide his county into suitable road districts, of such size and form as he shall deem best for the purpose of carrying out the provisions of this act; to define each and every public highway in his county, and file with the county clerk maps of all such roads of which no maps are already on file, and to open or cause to be opened all public highways which have been or which may hereafter be laid out and established according to law, and to survey and properly define the same; to take charge of the highways within his county, and to keep them clear from obstructions and in good repair; to cause banks to be graded, bridges and causeways to be made when necessary, to keep the same in good repair and renew them when destroyed; to make or cause to be made all plans and specifications for each and every bridge and road hereafter to be built or constructed, and to examine and report to the Board of County Commissioners of his county on all work when completed, and if said work is properly done according to the plans, specifications, and contract, then said County Surveyor shall draw his voucher for the same, and if said work was done under contract, then a copy of such contract shall accompany such voucher; to do and perform such other duties as are hereinafter provided in this act.

Section 2. Any ten residents of a road district may petition, in writing, the County Surveyor of the county to alter or discontinue any highway or to lay out a new highway therein. On receipt of a petition to alter, discontinue, or lay out a new road within his county, as is provided, it shall be the duty of the County Surveyor of the county to send two notices to one of said petitioners to post, which notices are to be posted, one at the

beginning and one at the termination of the road which it is proposed to alter, discontinue, or lay out, and the County Surveyor shall post a like notice at the door of the county clerk's office of said county. Each of said notices shall contain a description of the route of the road which it is proposed to alter, discontinue, or lay out, and shall state the place of beginning of the same and the terminus thereof. The chairman of the Board of County Commissioners, upon three days' notice from the County Surveyor, shall name one person to act as viewer of said road in behalf of said board, and such person shall be notified by registered mail by the County Surveyor to present himself at the place of beginning of said road at the time stated in said notice, to view said road, in company with the County Surveyor and one of the petitioners for said road, who shall have been duly appointed a viewer by the County Surveyor, and notified in like manner. Before beginning the view of any road, the County Surveyor shall require sworn proof of the posting of the notices herein provided for, and all notices shall be given at least ten and not more than forty days before the viewing of any road is made.

Section 3. After said viewers, chosen as above provided, have been sworn, they shall proceed to view the road which it is proposed to alter, lay out, or discontinue. If the petition asks for the laying out of a new road, and after having viewed said proposed road said viewers approve of the same, they shall immediately survey said proposed road, the County Surveyor to be assisted by the other viewers in the making of such survey.

Section 4. In case any person appointed as a viewer as above provided, for any reason, be unable to assist in the viewing or in the surveying of any road, then and in such case the County Surveyor and the remaining viewer may appoint some other suitable person to assist them in the performance of their duties.

Section 5. All roads hereinafter contracted shall be sixty feet wide, unless otherwise determined by the board of viewers viewing the same and approved by the Board of County Commissioners.

Section 6. The County Surveyor shall be chairman of all boards of viewers, and shall keep a full and accurate account of the proceedings of all such boards, and of all roads altered or discontinued, and of all roads laid out, naming the same, and shall give the place of beginning and length of all proposed roads, and how they are defined, their marks and corners, the grades, the character of ground, the land or premises over or through which any proposed road is to pass, the damages (if any) to the owner of the land over which the proposed road is to run, who acted with him as viewer, day or days engaged in viewing road, with all dates, together with the proof of posting of notices, all of which the County Surveyor shall report to the Board of County Commissioners, together with any suggestions as to the advisability of altering, discontinuing, or laying out any proposed road, and with an estimate of the probable cost of the same. This report will be made within fifteen days after the view of any road is had, as herein provided, and all such proceedings to view, lay out, discontinue, or alter any road shall be submitted to the Board of County Commissioners, and must be approved or rejected by them.

Section 7. The County Surveyor shall be the general superintendent

of all roads within his county and of the construction and alteration of all roads hereafter built or altered, and of all other work required to be done by him.

Section 8. The County Surveyor shall have power to employ suitable laborers, teams, and implements in the performance of any work required to be done by him under the provisions of this act, and to appoint some person as manager of such work, who shall at all times be under the orders and control of the surveyor of roads, and to receive labor in payment of the special road tax, as is by law provided. But no person employed as manager shall receive more than three dollars per day, and no such manager shall have less than five men under his direction at one time, except in the case of an obstruction, when, if necessary, a greater or less number than five men may be employed, and shall not expend in money or labor, or both, to exceed the sum of one hundred dollars without an order from the chairman of the County Commissioners.

Section 9. The County Surveyor shall have power to contract for the performance of any work required to be done by him, the cost of which shall not exceed in all the sum of one hundred dollars; and for doing or performance of any work required to be done by him, the cost of which, when completed, shall exceed the sum of one hundred dollars, the County Surveyor shall have power to contract, with the approval of a majority of the Board of County Commissioners of his county.

Section 10. The County Surveyor shall at the close of each quarter make to the Board of County Commissioners of his county an accurate and concise report of all roads and bridges, and of their condition and needs.

Section 11. The County Surveyor shall at all times keep himself informed as to the amount of money on hand and available in the general road fund, and at no time shall he exceed such amount without the consent of the Board of County Commissioners.

Section 12. The County Surveyor shall keep a record of all surveys made or caused to be made by him, and shall send a full report of each survey, together with the field notes and plan of the same to the Board of County Commissioners of his county, to be recorded in the book provided for the keeping of records of roads.

Section 13. The County Surveyor of each county shall receive as full compensation for the performance of his duties as County Surveyor in connection with the roads and otherwise the sum of five dollars per day; provided, that said compensation shall not exceed,

In counties of the eighth class, seven hundred and fifty dollars;
In counties of the seventh class, eight hundred dollars;
In counties of the sixth class, one thousand dollars;
In counties of the fifth class, twelve hundred dollars;
In counties of the fourth class, fourteen hundred dollars;
In counties of the third class, sixteen hundred dollars;
In counties of the second class, eighteen hundred dollars;
In counties of the first class, two thousand dollars.

Said compensation to be paid quarterly by the Board of County Commissioners after the accounts of said surveyor have been examined and approved by said board, and said surveyor must, before the Commissioners shall issue any warrants for any services rendered under this act, file with the said board an itemized account under oath.

Section 14. Viewers other than the County Surveyors, and all assistants of any County Surveyor, shall receive not to exceed three dollars per day for each day engaged or employed.

Section 15. It shall be the duty of the County Surveyor to make all maps provided for in Section 3,732 of the Political Code without extra charge.

Section 16. The office of Road Supervisor is hereby abolished. Any and all sections of Chapter 2 of Title VI of Part III of the Political Code relating to the powers and duties of Road Supervisors are hereby made applicable to County Surveyors in so far as the same are not inconsistent with any of the provisions of this act.

Section 17. All bills for road work must be presented, sworn to, audited, and allowed as other claims against the county.

Section 18. All acts or parts of acts in conflict with any provision of this act are hereby repealed.

Section 19. This act shall take effect and be in force from and after its passage.

Approved March 4, 1897, at 2.11 P.M.

ROBERT B. SMITH,
Governor.

As the road law is of great interest to the society, and as most of the County Surveyors in the State are members of the society, it was considered important that the road law be published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and the Secretary was directed to embody the same in the minutes of the meeting for publication. The meeting adjourned at about 11 P.M., to meet in the same place at 2 P.M. March 30, 1897.

A. S. HOVEY, *Secretary.*

SPECIAL meeting of the Montana Society of Engineers, held March 30, 1897. Meeting called to order at 2 P.M., Vice-President A. E. Cumming in the chair. A large number of members and County Surveyors were present. Reading of the minutes of the last meeting was dispensed with, and the time devoted exclusively to matters pertaining to the convention which had been organized and known as "The Montana Association for the Improvement of Public Highways." It was stated that the said association would adjourn on the following day, and the annual meeting would be in the same week of January next as the annual meeting of the Montana Society of Engineers. After two hours of discussion the meeting adjourned.

A. S. HOVEY, *Secretary.*

The regular monthly meeting of the Society was held in Helena, March 13, 1897. Meeting called to order at 8 P.M. by Vice-President A. E. Cumming. There was a large attendance of members and guests. An hour was occupied in discussing methods of road improvements. It was stated that the county commissioners of Lewis and Clarke County had agreed to adopt a new method, by which they expected to accomplish much more than heretofore, and at a saving to the county. It was the prevalent opinion that it was of great importance that the county surveyors meet and discuss their official duties. The following resolutions were passed and the Secretary was instructed to send a copy to John W. Wade, county surveyor of Lewis and Clarke county:

"In view of the State of Montana having taken the initiative in the United States of placing the construction and maintenance of the roads and bridges of the respective counties under the supervision of the county surveyor, by virtue of an act of the Fifth Legislative Assembly of the State of Montana, which became a law March 4, 1897, we hereby recommend and urge that each and every county surveyor endeavor to make the work under the new law operate to the material advantage of his county, both as to the saving of money and the substantial improvement of roads, and we further recommend that uniformity of method be employed, and to this end we suggest a convention of county surveyors at an early date. And therefore we request County Surveyor John W. Wade to call such a convention to meet in Helena. And we further suggest that each county surveyor extend an invitation to the county commissioners of his county to attend the convention and take part in its deliberations."

Numerous correspondence from county surveyors in the State was read, in relation to the new road law. One predominant sentiment in these letters was noticeable—the determination to make the new law a success in the matter of improvements and the saving of money in accomplishing the same.

Owing to the unusual amount of business before the Society, the paper from Charles Tappan, on "Mineral Surveys," was postponed until the next regular meeting of the Society. In the meantime the paper will be sent to the members, with a request for discussion and papers upon the subject.

There were two applications for membership, those of L. S. Griswold, geologist, of Helena, and H. M. Patterson, architect, of Butte. The newly-elected members were James S. B. Hollinshead, Godfrey Hughes, Geo. E. Moulthrop, Frank Scotten, Frank M. Smith, B. D. Whitten, F. W. C. Whyte, and W. F. Word. The two following charter members of the Society were elected honorary members: Edwin H. McHenry, chief engineer of the Northern Pacific Railway, and William A. Haven, engineer of the Erie Railway. Both were active in the organization of the Society, and have done much to promote its growth and usefulness. J. S. Keerl, F. J. Smith, and F. J. Taylor were appointed a committee upon credentials for membership. J. S. Keerl was appointed a committee of one to procure a paper for the next meeting.

A. S. Hovey, *Secretary.*

Association of Engineering Societies.

Vol. XVIII. APRIL, 1897. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

452D MEETING, APRIL 7, 1897.—The meeting was held at 1600 Lucas Place, at 8 P.M., with Vice-President Bryan in the chair. Thirty members and three visitors were present.

The minutes of the four hundred and fifty-first regular meeting and the two hundred and thirty-fourth meeting of the Executive Committee were read and approved.

The Secretary presented the application for membership of Mr. W. S. Williams, topographer, with the Mississippi River Commission, which was referred to the Executive Committee.

Mr. W. H. Bryan presented an obituary notice of the late John Barnwell Clements, a member of the Engineers' Club of St. Louis.

An invitation from the Western Drawing Teachers' Association to attend its fourth annual meeting was read.

The discussion of the evening on "The St. Louis Tornado" was then opened. Mr. Julius Baier presented a number of additional stereopticon views, showing the destructive action of the wind in St. Louis and at the bluffs across the river.

Mr. Robert Moore presented a report on wind pressures published by a commission appointed by Parliament after the fall of the Tay Bridge in 1880. This report gave many instances of extremely high wind pressures, and the speaker showed that it was as necessary in the construction of high buildings and structures to provide against horizontal forces as against vertical loads.

Professor F. E. Nipher cited scientific facts which had been noticed in other tornadoes, and discussed the relative accuracy of the different instruments used in measuring wind pressures. He showed that in most instances the actual pressure effect was inaccurately measured in the use of the manometer on account of the atomizer effect, and that in the use of pressure boards account must be taken of the suction effect on the leeward side of the board. He described and exhibited a new instrument which he had devised for measuring air pressures.

Mr. N. W. Eayres described the effect of the tornado on the east ap-

proach of the Eads Bridge, and gave a theory as to the manner in which this structure failed. He also made a plea for better horizontal bracing in all structures subject to wind pressures.

Mr. M. L. Holman gave formulæ which he had derived for the determination of the moment of stability of a large stack which had been overturned in the St. Louis tornado.

After the business the meeting adjourned to another room, where lunch was served.

RICHARD McCULLOCH, *Secretary.*

453D MEETING, APRIL 21, 1897.—The meeting was held at 1600 Lucas Place, at 8 P.M., with President Flad in the chair. Twenty members and nine visitors were present.

The minutes of the 452d regular meeting and the 235th meeting of the Executive Committee were read and approved.

The application for membership of Mr. W. S. Williams having been favorably reported upon by the Executive Committee, this gentleman was balloted for and elected a member of the club.

The secretary announced that he had received an application for membership from Mr. W. L. Garrels, engineer for the Fruin-Bambrick Construction Company. This application was referred to the Executive Committee.

A number of contributions to the library were then announced.

Then followed the paper of the evening by Colonel E. D. Meier, entitled "A National Boiler Inspection Law." A review was given of the present status of boiler laws and boiler inspection, and a plea was made for the passage of a national boiler inspection law, the execution of which is to be entrusted to a bureau of the new Department of Commerce and Industries.

The discussion which followed was participated in by Messrs. Ockerson, Barth, Baier, Flad, and Corey.

Mr. Robert Moore made a few remarks on the death of William Ezra Worthen, honorary member of the Engineers' Club of St. Louis, and presented the following resolution, which was adopted:—

"*Resolved,* That the Engineers' Club of St. Louis have learned with great regret of the death of William Ezra Worthen, an honorary member of this club, and we desire hereby to express our appreciation of his high attainments as an engineer and his noble traits as a man, and to tender to his family our sympathy in their great loss."

Colonel E. D. Meier followed with a few remarks on the life and attainments of Mr. Worthen.

The meeting then adjourned to another room, where lunch was served.

RICHARD McCULLOCH, *Secretary.*

Civil Engineers' Club of Cleveland.

THE APRIL MEETING of the club was held at the Electricity Building Case School of Applied Science, Tuesday evening, April 13, 1897, President Ritchie in the chair. Present, 30 members and 60 visitors, among whom were a large number of ladies.

Messrs. C. M. Barber and A. L. Hyde were appointed tellers to canvass the ballots for new members.

The applications of John N. Dodd for admission to active membership and of Francis Line and Arthur McAllister for admission to associate membership were read.

On motion of Mr. Hyde, the regular business was dispensed with, and the address of the evening was then given by Dr. Cady Staley, president of the Case School of Applied Science, on "The Arch in Architecture." The talk was beautifully illustrated with lantern views. It gave a most complete and interesting description of the arch, from the earliest to modern times.

Robert R. Muir was elected an active, and Albert C. Bishop an associate, member.

F. A. Coburn, *Secretary.*

Montana Society of Civil Engineers.

The Regular Monthly Meeting of the society was held in the office of Hovey & Bickel, Helena, Mont., April 10, 1897. President C. W. Goodale called the meeting to order at 8 P.M. The minutes of the last meeting were read and approved. F. J. Smith and F. J. Taylor were appointed tellers to canvass the letter ballots for membership, those elected being as follows: L. S. Griswold, geologist of Helena; H. M. Patterson, architect of Butte; Benjamin Bond, County Surveyor of Beaverhead County; Donald Bradford, Arid Land Commissioner of Montana, and E. M. Wardwell, County Surveyor of Broadwater County. It was stated that the paper by Charles Tappan upon "Mineral Surveys" had been sent to Butte for discussion and would be read at the next regular meeting of the society.

A discussion ensued upon keeping up the standard of membership of the society, and the advisability of changing the title of the present associate members to corresponding members, and to provide for the admission of those associate members who are qualified by practical experience to co-operate with engineers in the advancement of professional knowledge.

Mr. F. McRae was appointed a committee of one to revise the memorial of Colonel W. W. DeLacy for the purpose of publication in the Journal of the Association of Engineering Societies. The life of Colonel DeLacy was very remarkable, owing to his adventures in the West at a very early date, while following his profession.

The meeting adjourned at 10.30 P.M.

A. S. Hovey, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., April 5, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Ten members and six visitors present. President Hilgard called for one or two reports, on which more time was requested. Mr. Münster, at whose instance some experiment on the shearing value of wire nails in pine planks have been

made at the State University, introduced Mr. Walker and Mr. Cross, the students who are making the tests. They displayed samples and gave some general results of about 200 tests of the various sizes of nails, in white and Norway pine. A white pine joint held by one 6d. nail begins to yield at about 70 lbs. of shear, and gives way at about 160. Held by a 60d. nail the corresponding figures are 370 and 820, the maximum figure in all cases being about twice that which indicates the point of yielding. Roughly, the strength of the joint is the cube of the diameter of the nail into 50,000. The largest nails can be driven 1⅛ inches center to center and nearly the full value of the nail is effective. For instance, the result for one 50d. nail to the joint was 347 and 800, while the average of nine 50d. nails to the joint was 294 and 790. These experiments will be extended and the results tabulated and digested, and at a future meeting of the Society will be discussed.

President Hilgard read a few notes on the generally-overlooked centrifugal and wind forces which a pile bridge has to resist, and laid out considerable matter for discussion at the next meeting. He closed with an interesting account of his hospitable reception last month by members of the Boston Society.

C. L. Annan, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, Cal., Regular Meeting, April 2, 1897.—Called to order by Past President Dickie. The minutes of the last regular meeting were read and approved.

The following gentlemen were elected to membership: Members: Edward T. Hewitt, of San Francisco; Morton L. Tower, of Empire City, Oregon.

The applications of Henry A. Schulze, architect, of San Francisco, proposed by Herman Barth, G. W. Percy, and Adolph Lietz, and O. M. H. Denio, of Vallejo, mason at Navy Yard, Mare Island, proposed by Otto von Geldern, Geo. F. Schild (per O. von G.), and Ernest F. Rossow (per O von G.), were read.

The topical subject of the evening: "High Building Construction," was discussed, Mr. Percy carrying on the main discussion, which was participated in by members present.

The attention of the Society was called by the Secretary to the musical entertainment, arranged by Director Hermann Barth, which is to take place in the Society's rooms on or about April 20, the program therefor to be circulated to members in due time.

Otto von Geldern, *Secretary.*

William Albert Allen.—A Memoir.

By H Bissell and E. W. Howe, Committee of the Boston Society of Civil Engineers.

[Read January 27, 1897.]

William Albert Allen, the eldest son of Rev. Charles F. and Ruth S. Allen, was born at Bath, Me., October 18, 1852. He was a descendent, in the eighth generation, of George Allen,, who was born in England in 1568, and came to New England in 1635. George Allen's grandson, James Allen, was one of the original proprietors of Martha's Vineyard, and five generations of the family lived on that island. Rev. Charles F. Allen, D.D., was the first president of the Main State College, and for over fifty years was one of the leading clergymen of the Methodist Church in Maine.

Mr. Allen attended the public schools of Portland, Eaton School at Morridgewock, graduated from the Bangor High School, Kent's Hill Seminary, and from Maine State College, where in 1874 he received the degree of Civil Engineer. He soon after entered the service of the Maine Central Railroad, and in January, 1885, was appointed chief engineer, which position he held until his death, March 21, 1896, caused by falling from a train crossing the Androscoggin River while inspecting repairs which were being made to the piers of the bridge. He was also chief engineer of the Portland Union Railway Station Company from the commencement until the completion of the work. His wife, Ella, daughter of Samuel Rolfe, Esq., of Portland, Me., died in 1895. They had no children.

Mr. Allen was elected a member of the Boston Society of Civil Engineers April 15, 1885, and of the American Society of Civil Engineers May 6, 1891.

Mr. Allen's high natural abilities with his technical education made him a valuable man in his position. He won and held the respect and confidence of the officials and men on the road, and all others with whom he came in contact to an unusual degree. On the excursion of the American Society of Civil Engineers to the White Mountains in 1895, Mr. Allen, as representative of the M. C. R. R., looked after the interests and comfort of the party, contributing largely to the pleasure of the occasion, yet doing it all so quietly and modestly that probably many were unaware of his presence

One of his associates says of him: "Beneath an unassuming and modest bearing, behind a quiet but genial manner lay a respect for duty, and a keen appreciation of the finer discriminations of business honesty extending to the minutest detail of every day life. His unselfish regard for others, his constant care for the welfare of those about him were characteristics of which those with whom he came in contact were constantly reminded. In many ways not pertaining strictly to his own department of work, Mr. Allen by his tact, ready pen and sound judgment, rendered most valuable service to the Maine Central Railroad. For his true hearted and manly characteristics among men of affairs throughout the State of Maine,

Mr. Allen was held in high esteem, and his sad death brings real sorrow to a wide circle of representative business men who had learned to regard him as one of the most conspicuous of the younger professional men of the State."

John Barnwell Clements.—A Memoir.

By William H. Bryan, Member, Engineers' Club of St. Louis.

[Read April 7, 1897.]

It has become a custom with this club to spread upon the records memorials of deceased members—a practice well worthy of being perpetuated. The epitaph of the engineer can be written in no better place than in the Transactions of his Society. When asked, therefore, by President Flad, to perform this duty in the case of John B. Clements, I could not do otherwise than respond.

The tragical death of Mr. Clements on March 17th last, at Hot Springs, Ark., is still fresh in your minds. That the act was performed during temporary aberration is beyond doubt.

For several years past I have had frequent occasion to come in close contact with Mr. Clements, and have noticed recently that he was permitting himself to be unduly worried by business matters, although there was really no occasion for anxiety in any direction. His unfortunate end is clearly traceable to too close application to his varied business interests. He steadfastly devoted the entire energies of a brilliant mind to the attainment of whatever object was in view. This is, unfortunately, a failing too common among engineers, and warnings against it cannot be reiterated too often.

Mr. Clements was born in London, England, in 1851, his parents coming to America and settling in St. Louis when he was eight years of age. His education was received in this city. His first employment was with the Iron Mountain Railway System in a most humble capacity. By energy, ability, intense loyalty, and close application to duty he rose rapidly, reaching in a few years the position of chief assistant engineer. On the consolidation of the Iron Mountain with the Missouri Pacific Railway, he received the appointment of principal assistant engineer for the entire Missouri Pacific system.

Among the important pieces of work which came under his immediate supervision was the construction of the Oak Hill or Carondelet branch. A special feature of his work was the company's rights-of-way and their property interests, particularly in and near St. Louis. For some years he worked on the profiles, records, and indexes in the engineer's office, bringing the whole into a most systematic and complete arrangement.

In 1889 he resigned this position to become vice-president and general manager of the Christy Fire Clay Co., to the active management of whose business he devoted his best energies up to the time of his last illness. His work here was of the same high order, being the reduction of all the departments of the work to a system, the introduction of labor-saving devices wherever possible, including the construction of a gravity road for han-

dling clay. His special study was the improvement of the output of the company and its adaptability to severe and unusually trying conditions, such as resistance to the fluxes, and high temperatures met in the manufacture of glass.

Mr. Clements was identified with many other prominent interests in this city, being president of the St. Louis Sanitary Co., principal owner of a Carondelet bridge franchise, and also largely interested in industrial enterprises in the West and South.

He became a member of this Club on January 7, 1885, and, while taking an active part in its proceedings, he was always one of its stanchest supporters. He was also a member of the American Society of Mechanical Engineers, and contributed materially toward making the Convention in this city a year ago a success.

In my association with Mr. Clements, I found him always a pleasant and courteous gentleman, a man with the true engineer's instinct of getting at the essential features of a problem in the shortest time, and the the most direct manner; a man of rare executive ability, and of a most charitable disposition. An incident illustrating the latter trait was strongly impressed upon me some years ago, in connection with a gentleman—once a member of this Club—where Mr. Clements went out of his way to do a kindly action in the face of most forbidding circumstances.

There came to him more of substantial rewards than fall to the lot of most engineers. There is much in his character and career which compels admiration, and in many respects his example can well be followed. On the whole, however, we may be pardoned for doubting whether his success was worth the price he paid for it, after all.

Whole-souled, rare-minded men like John B. Clements are too scarce in this busy world at the end of the nineteenth century. In honoring such men the Engineers' Club of St. Louis honors itself.

The Detroit Engineering Society.

Annual Meeting.—The third annual meeting of the Detroit Engineering Society was held in the parlors of the Hotel Ste. Claire, Friday evening, April 23, 1897, President Walter S. Russel presiding. There were present thirty-six members.

The Executive Committee reported favorably upon the applications for membership of C. M. Stephens, of Mt. Clemans, and A. J. Wenzell, of Detroit, and upon secret ballot they were elected to resident membership.

The election of officers followed, which resulted in the election of the following:

President—Jesse M. Smith.
First Vice-President—Alex. Dow.
Second Vice-President—William J. Keep.
Secretary—Gardner S. Williams.
Treasurer—Theodore H. Hinchman, Jr.

The annual reports of the Secretary and Treasurer were then submitted by title, and the meeting adjourned to the dining room and participated in

the annual banquet, at which the President delivered his annual review of the work of the society, and impromptu responses were made by Messrs. Dow, Farmer, D. A. Molitor, Conant, Greene, Field and Smith.

GARDNER S. WILLIAMS, *Secretary.*

The Executive Committee met April 27, and selected Mr. Willard Pope to complete the committee, and nominated Mr. William A. Livingstone as member of the Board of Managers of the Association of Engineering Societies.

GARDNER S. WILLIAMS, *Secretary.*

ANNUAL REPORT OF THE SECRETARY.

To the President, Executive Committee and Members of the Detroit Engineering Society:

The preliminary meeting for the formation of this society was held at the office of the Engineering Department of the Detroit Water Works Wednesday evening, May 1, 1895, and the original name, "The Detroit Association of Graduate Engineers of the University of Michigan," adopted upon motion of Mr. W. A. Livingstone. Mr. G. S. Williams was elected temporary chairman, and Mr. C. W. Hubbell temporary secretary. The constitution was adopted at a second meeting at the same place Tuesday evening, May 28, and the first permanent officers were elected at the third meeting, which preceded the first annual banquet held at the Michigan Club Rooms, Chamber of Commerce, Friday evening, June 14, 1895, the officers being:

President—Walter S. Russel.

First Vice-President—William A. Livingstone.

Second Vice-President—George Y. Wisner.

Secretary—Edmund L. Sanderson.

Treasurer—George A. Robinson.

These officers then selected G. S. Williams to complete the Executive Committee.

The following meetings were held during the year:

August 23, on board steamer "Newsboy" on Detroit River. President Russel presiding, 15 members and 8 guests present. Paper by George Y. Wisner, "Regulation of Lake Levels."

November 8 at Prismatic Hall, President Russel presiding. Paper by H. G. Field, "Test of a Direct-Connected Dynamo."

December 20, at Hotel Ste. Claire, President Russel presiding. Paper by G. S. Williams, "The Purification of Water."

January 24, 1896, at Hotel Ste. Claire, President Russel presiding. Paper by H. E. Whitaker, "Inertia, a Neglected Element in Machine Design."

February 28, at Hotel Ste. Claire, President Russel presiding. Paper by T. H. Hinchman, Jr., "Test of a Carbon Bi-Sulphide Engine."

The second annual meeting and annual banquet were held at Hotel Ste. Claire Friday evening, May 1, 1896, President Russel presiding and 20 members present. The report of the Secretary showed that during the year 42 persons had been connected with the society, of whom four had withdrawn. The constitution was amended, extending the privileges of membership to engineers in general, and 26 new members were elected. The

name of the association was then changed to "The Detroit Engineering Society," and the following officers elected:

President—Walter S. Russel.
First Vice-President—Jesse M. Smith.
Second Vice-President—Alex. Dow.
Secretary—Gardner S. Williams.
Treasurer—Theodore H. Hinchman, Jr.

The Executive Committee was completed by the selection of William A. Livingstone, and was directed to revise the constitution to provide for the changed conditions of membership.

The following meetings have been held during the year just closed:

May 29, 1896, at Hotel Ste. Claire, President Russel presiding; 26 members and 4 visitors present. Paper by Charles E. Greene, "The Evolution of the Engineer."

June 19, at Hotel Ste. Claire, Vice-President Smith presiding; 23 members and 10 visitors present. Paper by J. C. Danziger, "High Grade Steel." Twenty candidates elected to membership, and constitution reported and laid on table.

July 24, called at Palm Leaf, but adjourned for lack of quorum.

August 21, called at Palm Leaf, but held at Hotel Ste. Claire on account of rain, President Russel presiding; 17 members and 5 visitors present. Paper by Geo. Y. Wisner, "Sewage Disposal." Six candidates elected to membership.

September 18, at Hotel Ste. Claire, President Russel presiding; 17 members present. Paper by David A. Molitor, "Municipal Public Improvements and the Laws Governing Them."

October 16, at Hotel Ste. Claire, President Russel presiding; 23 members present. Paper by A. G. Mattsson, "The Development in Machinery of Our Lake Marine."

November 20, assembled at Hotel Ste. Claire and proceeded to Detroit Citizens' Street Railway power-house in private car "Yolande" by invitation of Mr. Thomas Farmer, Jr. Meeting on board car "Yolande." President Russel presiding; 23 members and 8 visitors present. Three candidates elected to membership.

December 18, at Hotel Ste. Claire. President Russel presiding; 24 members and 3 visitors present. Executive Committee reported that on letter ballot 54 of 58 votes were favorable to increasing dues and joining Association of Engineering Societies, and were instructed to apply for admission. Constitution taken from the table and referred back to Executive Committee for further revision. Seven candidates elected to membership. Paper by Alex. Dow, "Conduits and Cables."

January 22, 1897, at Hotel Ste. Claire. President Russel presiding; 25 members and 5 visitors present. Paper by Edward L. Woodruff, "Fog Signals and Aberrations in Their Audibility." The revised constitution reported, adopted and ordered printed. Two candidates elected to membership. The admission of the society to membership in the Association of Engineering Societies was announced.

February 19, at Hotel Ste. Claire. President Russel presiding; 25 members and 1 visitor present. Paper by R. G. Ewer, "Sulphuric Acid and By-products from Iron Pyrites," read by the Secretary.

Chas. E. Greene nominated and confirmed as member of the Board of Managers of the Association of Engineering Societies. A standing committee on Legislation and one on Public Library was authorized and appointed. One candidate elected to membership.

March meeting postponed to April 2, at Hotel Ste. Claire. President Russel presiding; 25 members and 5 visitors present. Paper by W. S. Russel, "Observations on the Chicago Drainage Canal." Five candidates were elected to membership.

During the year 70 candidates have been elected to membership, of whom eight have not yet qualified, and six members have resigned, four on account of removal from the State, leaving the present membership 94, a gain of 56 during the year.

Respectfully submitted,
GARDNER S. WILLIAMS, *Secretary.*

REPORT OF THE TREASURER.

To the President and Executive Committee of the Detroit Engineering Society:

Total receipts during the year ending May 1, 1896	$205 25
Total disbursements during year ending May 1, 1896	204 35
Balance on hand	$1 90

For year ending April 23, 1897:

RECEIPTS.

From Treasurer of preceding year	$1 90	
Dues of members for 1896	177 00	
Total		$178 90

EXPENDITURES.

Printing, stationery and postage	$40 17	
Initiation in Association of Engineering Societies	41 50	
Quarterly assessment of same	68 25	
Total		$149 92
Balance on hand		$28 98

Respectfully submitted,
THEODORE H. HINCHMAN, JR., *Treasurer.*

Association of Engineering Societies.

Vol. XVIII. MAY, 1897. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

454th Meeting, May 5, 1897.—The meeting was held at 1600 Lucas Place at 8 p.m., with President Flad in the chair. Thirty-four members and nine visitors were present.

The minutes of the 453d meeting and the 236th meeting of the Executive Committee were read and approved.

The application for membership of Mr. W. L. Garrels having been favorably reported upon by the Executive Committee, this gentleman was balloted for and elected a member of the Club.

The Secretary announced that Professor J. B. Johnson had presented the library with a copy of "The Materials of Construction." Mr. Julius Baier, the Librarian, announced that he had received for the library copies of the reports of construction of the Sioux City, New Omaha, Plattsmouth and Cairo bridges designed by Mr. Morrison. The Secretary was instructed to thank these gentlemen in the name of the Club for their donations.

The paper of the evening by Mr. W. A. Layman, entitled "Long Distance Electric Power Transmission," was then read. The writer briefly reviewed the methods of electric power generation and the different systems of electric transmission, and showed how the two and three-phase electric currents are peculiarly adapted to long distance transmission, illustrating his remarks by means of charts and apparatus. He described in detail the recent installations at Sacramento and Fresno, Cal., Telluride, Colo., and Salt Lake City, Utah. Lantern slides showing views of these plants were exhibited. The paper was received with a great deal of interest, and the discussion which followed was participated in by Messrs. Bryan, Flad, Bausch and Laird.

Following this paper, Mr. C. G. Barth made an address on "Columns." He showed the result of eccentric loading, and gave a new formula which he had derived for use in the designing of columns. He exhibited curves showing how his formula compared with those in common use. On motion Mr. Barth was requested to put his remarks in writing with a view to publication.

The meeting then adjourned to the library, where lunch was served.

Richard McCulloch, *Secretary.*

455TH MEETING, MAY 19, 1897.—The meeting was held at 1600 Lucas Place at 8 P.M., with President Flad in the chair. Thirty-one members and four visitors were present.

The minutes of the 454th regular meeting and the 237th meeting of the Executive Committee were read and approved.

The Secretary announced that Mr. B. H. Colby had presented the library with a copy of "The Report upon the Bench Marks of the City of St. Louis." The thanks of the Club were extended to Mr. Colby for his donation.

Mr. H. A. Wagner then made an address upon "The Electric Lighting System of the City of St. Louis." A review was given of the history of the lighting industry in this city, and the present condition was described. Changes are now being made so that all lights may be operated from one kind of dynamo. Twelve hundred arc lamps are now being operated from one alternating current dynamo, and the other arc lights are rapidly being changed to operate on alternating current circuits. The plan in operating arc lights is to use step-up transformers, and as many as sixty arc lights are operated in series on one alternating circuit. The same generator may be used for arc and incandescent lighting. Mr. Wagner gave a short sketch of the underground work now being installed. For commercial lights the plan is to use high-tension mains and distribute at low tension on the 220-volt, three-wire system, from transformers placed in the manholes. The discussion which followed was participated in by Messrs. Kinealey, Flad and Barth.

Mr. Barth then exhibited a wooden surface illustrating a problem in the calculus, and gave a short discussion of the matter.

The meeting then adjourned to the library, where lunch was served.

RICHARD MCCULLOCH, *Secretary*.

Montana Society of Engineers.

REGULAR MEETING, MAY 8, 1897.—The regular monthly meeting of the society was held in its rooms in the Merchants' National Bank Building. The presiding officer being absent, James H. Page was elected president, *pro tem.* The minutes of the last meeting were read and approved. The applicants for membership were P. C. Kittle, of Belt, and A. W. Warwick, of Wickes. Mr. Finlay McRae, Committee on the Colonel W. W. De Lacy Memorial, presented the same. It being found that there were not sufficient funds for its publication, resolutions were passed to request members to contribute funds for its publication, and also to erect a suitable monument over the grave of the late Colonel W. W. De Lacy. A motion prevailed to hold a special meeting at 8 P.M., May 15.

SPECIAL MEETING, MAY 15, 1897.—Mr. F. L. Sizer was elected president, *pro tem.*, and Mr. T. M. Ripley was appointed temporary secretary. The minutes of the preceding meeting were read and approved. The application for membership of Mr. G. R. Metlen, of Dillon, was favorably acted upon. A paper upon "Mineral Surveys," from Mr. Charles Tappan, of Salt Lake City, Utah, was read. The paper gave a method of taking direct solar observations, and suggested methods of meeting some of the diffi-

culties and absurdities arising through the present mining laws and department rulings. A discussion upon Mr. Tappan's paper from Mr. John Herron was read, in which he showed the importance of carefully surveying mining claims, as contemplated by Mr. Tappan's methods. A discussion by Mr. Joseph H. Harper was also read. He considered the occasions were rare where the deputy was required to work to obtain the last few square feet that may be included in a survey. Other conditions generally control. Mr. F. L. Sizer thought that the present ruling prohibiting the establishment of end lines inside the boundaries of patented ground would eventually be modified. It was announced that Professor L. S. Griswold would probably deliver an address upon his geological research in Montana at the next regular meeting.

A. S. Hovey, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, May 7, 1897.—Called to order at 8.30 p.m. by Past-President Richards.

A letter from President Molera was read, expressing regrets that he could not attend the meeting.

The minutes of the last regular meeting were read and approved.

The following were elected to membership:

Members—Henry A. Schulze, architect, San Francisco; George H. Evans, mining engineer, Oroville, Cal.

Junior—E. F. Henderson, civil engineer, Berkley, Cal.

Associate—O. H. M. Denio, Vallejo, Cal.

The Secretary read the paper of the evening, written by Mr. Burr Bassell, member of Technical Society, entitled "Operation of the Los Angeles Out-fall Sewer and Sewage Irrigation."

In connection therewith, written discussions by James D. Schuyler, member of Technical Society, and Gervaise Purcell, A. M. I. C. E., were read.

A further discussion of the interesting subject was, upon motion by D. C. Henny, postponed until the next regular meeting.

Mr. L. A. Buchanan explained a method on the blackboard of solving algebraic equations of any degree.

It was suggested that Mr. Buchanan furnish the members with copies of his solution, for closer examination and future discussion of the subject.

The Chairman appointed a committee consisting of Colonel George H. Mendell, George W. Dickie, and President Molera, to wait upon Colonel Charles R. Suter, Corps of Engineers, U. S. A., and request him to address the society on the subject of the Mississippi river on some suitable occasion.

The death was announced of Alexander J. Brownlie, member of Technical Society, of Portland, Ore. The matter was referred to the Executive Board for the preparation of suitable resolutions in memory of the deceased engineer.

Adjourned.

Otto von Geldern, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., May 3, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 P.M. Seven members and two visitors present; Vice-President Crosby presiding and Mr. Wilson acting as Secretary.

Minutes of previous meeting read and approved.

A communication to our President from the President of the Engineers' Club of St. Louis relating to an interchange of lantern slides, and the favorable reply thereto were read.

Action on the report of the Committee on Membership was deferred until the next regular meeting.

A paper prepared by President Hilgard, on "Some Standard Plans for Girder Bridges on the N. P. Railway System," was then presented. The paper set forth the economical and other advantages of the standard 100 ft. plate-lattice girder designed by Mr. Hilgard, which has been in use for the past two years. The method of replacing (in the space of about four hours) the old structure on temporary foundations with the new girder bridge on concrete foundations previously built was definitely described. The pound prices for bridge complete contracted for in 1895 averaged 3½ cents, in 1896 about 3 cents, and will not exceed 2¾ cents the present year. Mr. Hilgard's scheme of complete standard plans of uniform size blue printed from photographic negatives, for bidders, inspectors and office use furnishes in abundance at small cost the details so necessary to definite treatment of this class of work.

The matter of illustrations for the paper on Wire Nail Tests read at the last meeting was referred to Mr. Woodman and Mr. Münster.

Adjourned to first Monday in September.

C. L. Annan, *Secretary.*

Civil Engineers' Club of Cleveland.

Case Library Building, Cleveland, O.—Meeting of the Civil Engineers' Club of Cleveland, Tuesday evening, May 11, 1897, President Ritchie in the chair. Present, twenty-four members and five visitors.

The minutes of the annual meeting, held February 23, the special meeting of March 6, and the April meeting on the 13th were read and approved.

The Executive Board reported the names of Messrs. J. B. Weddell and John B. Davis as dropped from the roll for the non-payment of dues. The resignations of Messrs. Frank H. Constant, H. E. Riggs, and John Walker, and the applications for active membership of George Harry Kimball and John Bruce Hayden as approved.

The Standing Committees for the year as follows:

Finance Committee—C. M. Barber, F. A. Coburn, Hiram Kimball.

Library Committee—A. Lincoln Hyde, J. W. Langley, William C. Jewett.

Programme Committee—Albert H. Porter, chairman; Henry A. Barren, Walter Miller, Harry S. Nelson, W. P. Brown, Joseph C. Beardsley, Perry L. Hobbs.

Reception Committee to consist of the entire board.

The resolutions regarding the manner of the payment for lunches presented at the annual meeting came up for action and failed to be adopted.

Mr. Walter Miller then presented the paper of the evening, "Some Notes on Marine Engineering and Shipbuilding in England, Scotland and Ireland."

It was a very complete collection of notes describing observations by the reader during his recent trip through the shipbuilding yards and machine shops and foundries of those countries. An interesting discussion followed.

John N. Dodd was reported as elected to active membership, and Francis Line and Arthur McAllister, Jr., to associate membership.

The meeting adjourned, after which a light lunch was served.

F. A. Coburn, *Secretary.*

Boston Society of Civil Engineers.

April 21, 1897.—A regular meeting of the society was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., Vice-President H. D. Woods in the chair; eighty-five members and visitors present.

The record of the last meeting was read and approved.

Messrs. Frederic A. Caldwell, Stephen Child, Arthur E. Hatch, Kilburn S. Sweet, Leonard C. Wason, and Thomas H. Wiggin were elected members of the society.

The secretary reported for the Board of Government that it had appointed the following special committees:—

On Weights and Measures—Charles T. Main, Dwight Porter, Henry B. Wood.

On Excursions—Morris Knowles, Austin B. Fletcher, R. S. Hale, Henry S. Adams, B. W. Guppy.

On the Library—William B. Fuller, F. L. Fales, C. M. Saville, F. P. McKibben, F. H. Fay.

On Quarters—Thomas Doane, Desmond Fitzgerald, E. W. Howe, C. Frank Allen, E. W. Bowditch.

On Municipal Civil Service—William Jackson, F. P. Stearns, G. F. Swain, G. A. Kimball, T. H. Barnes.

Members of the Board of Managers—J. R. Freeman, Henry Manley, Fred. Brooks, and the secretary *ex-officio.*

The secretary read a memoir of Marshall M. Tidd, prepared by a committee of the society.

The thanks of the society were voted to the officials of the New York, New Haven and Hartford Railroad, who had placed at the disposal of the society the special cars for the excursion to Brockton this afternoon.

Mr. James W. Rollins, Jr., then read the paper of the evening, entitled "Construction Work in Abolishing the Grade Crossings in Brockton, Mass." The paper was fully illustrated by lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Marshall Martain Tidd.—A Memoir.

By Henry Manley, J. R. Freeman and B. R. Felton, Committee of the Boston Society of Civil Engineers.

[Read April 21, 1897.]

Marshall Martain Tidd was born in Woburn, Mass., August 1, 1827. His early education was obtained in the public schools of Woburn. He lost the use of his right arm when a young child, owing to a fall upon the back of his head, which resulted in the paralysis and arrest of growth of the arm. Notwithstanding this, he was a very active and capable boy, and delighted in all kinds of out-of-door sports, such as swimming, sailing, canoeing, hunting, fishing, skating, etc., in all of which he excelled, in spite of the loss of the use of his right arm.

He was expert in the use of tools, and made many ingenious articles that required skillful work.

At the age of 16 he went to work on the old Middlesex Canal, and for about two years tended one of the locks in Woburn.

His first engineering experience was as an assistant on the dam at Lawrence, under Mr. Charles S. Storrow, chief engineer. This was before the days of photography, and one of his duties was to make free-hand sketches showing the condition of the work at the end of each month. He had much ability in the use of pen, pencil and brush, and his drawings were remarkable for their extreme accuracy and for their fineness of detail.

After the Lawrence dam was completed he found employment in a lithographing establishment, where he remained for a year or two, making drawings on stone.

After this he opened an office in Boston for the practice of draughting. His work was mostly mechanical draughting and making drawings of machinery for wood-cuts. He finally settled in an office at the corner of Tremont and Court streets, which he occupied for over forty years, and, indeed, to the end of his life, with the exception of the time occupied by the erection of a new building on the site of the old one. His work brought him into contact with many mechanical inventors and to an acquaintance with many noted men in this field. He made drawings of many of the leading forms of wood and iron-working machinery, and of the work of Hoadley, Worthington, Alvan Clark and others; also many drawings of natural specimens for Professor Agassiz. His scrap-book, containing cuts from his drawings, is exceedingly interesting, and gives, in a way, a pictorial history of the mechanical achievements of the time. Mr. Tidd always referred to this work with much satisfaction, as well he might, for notwithstanding that he had only his left hand to work with, in this was cultivated such marvellous delicacy of touch that he probably had no superior in machine drawing in Boston. He followed this work until about 1872, when the decline in the use of wood-cuts, due to the introduction of cheaper processes of illustration, and his employment on the construction of water works, led to his giving it up entirely. During these years, however, he was employed more or less upon work more in the line of civil engineering. His most important work of that nature was upon the patent wooden dry docks built by J. E. Simpson at Erie Basin, Brooklyn, N. Y., East Boston, Mass., and Portland, Me.

In 1872 Mr. Tidd was elected Water Commissioner of Woburn, Mass., the only public office he ever held. In addition to his duties as Commissioner, he was practically engineer of the works. His connection with these works led to his employment on others, and from this time he devoted himself almost exclusively to the design and construction of water works and sewerage systems. The following are the more important water works that came under his charge, in about the order in which they were built: At Natick and Lincoln, Mass.; Lewiston, Me.; Concord, Mass., State Prison; Hingham, Marlboro, Hudson, Weymouth and Hyde Park, Mass.; Gardiner, Richmond and Calais, Me.; St. Stephens, N. B.; Cohasset, Randolph, Holbrook and Vineyard Haven, Mass.; Charlottetown, P. E. I.; Malden, Mass., High Service; Caribou, Dover and Foxcroft, Me.; Ashland, Ky.; Reading and Fairhaven, Mass.; Hanover, N. H.; Farmington and Madison, Me., and Yarmouth, N. S.

In addition to the foregoing, he was employed to make improvements or additions to existing works in Fort Smith, Ark.; Tiffin, Ohio; Woonsocket, R. I.; Manchester, N. H.; Bath, Brunswick, Waterville, Bangor, and Bar Harbor, Me.; Medford, Melrose, Belmont, Maynard, and Attleboro, Mass.

He was employed as an expert to report to capitalists upon the condition and value of many works in the West; also as an expert in cases of the taking of the works of private corporations by municipalities at Syracuse, N. Y.; Auburn, Me.; Rochester, N. H.; Braintree, Haverhill, and Quincy, Mass., and Milford, N. H. He was retained as consulting engineer at Helena, Mont.; Phœnix, Ariz., by the Maine Water Company, Cambridge, Mass., and others. He also designed and built the sewerage system at Marlboro, Mass.

At the time of his death he was employed upon the Bath Water Works, Me., the construction of the Woburn sewerage system, a plan of a sewerage system for Stoneham, Mass., the Bar Harbor Water Works, as consulting engineer on the Willimantic, Conn., and Cambridge Water Works, and as one of a board of arbitration in a suit for mill damages against the town of Attleboro, Mass. He was engaged also to make plans for a high-service system at Lawrence, Mass.

As an engineer, Mr. Tidd's most striking traits were his remarkable mechanical ability, his keen observation, his fertility of resource, and his entire honesty of purpose.

In all of the many works he has designed and built he made no serious mistakes—no mistakes that led to failure or to the rebuilding or abandonment of any of his work. To accomplish this result, he was not guilty of a lavish or wasteful expenditure, and his works were as economically built as was consistent with excellence.

As a man he was always genial and a good companion; his speech was forcible and always direct; in both his speech and acts he was thoroughly honest. He was a man of strong prejudices, a good friend, but also a good enemy when he considered himself ill-treated. In his relations with the members of his profession he was liberal and generous, ever ready to impart freely of his knowledge or from the result of his experience to a brother engineer who came openly to him. He was never too busy to freely advise a young engineer, and to open to him his own note-books and working drawings with the utmost patience and good-will.

His relations with his assistants were pleasant; he was always ready to assist them in the profession; he never seemed to fear that they would learn too fast, but placed them in important positions whenever possible. He was certainly a good engineer for a young man to work with.

To know a man completely, it is necessary to know his recreations as well as his work. In earlier life Mr. Tidd's recreations were of the active, out-of-door sort. Later in life his greatest interest was, perhaps, in horticulture and the care of his grounds. For a man of moderate means he had a very fine collection of shrubbery; his flowers, fruit trees, and lawn were kept in the best of order, and his grounds showed remarkable taste. He was a life-member of the Massachusetts Horticultural Society, and was wonderfully well-informed in the details of raising fruit and flowers and the care of shrubbery. Another of his favorite recreations was found in the small workshop at his home, which was a model in its equipment of tools and their neat arrangement. Purely as a matter of recreation, he would often repair an instrument for draughting or engineering, fitting and finishing the new part with all the skill of an expert instrument-maker. In this, as in his draughting or in his earlier accomplishments of swimming and gunning, he appeared to take a quiet satisfaction in becoming able to accomplish all that could be done by one with a good right hand. His other principal recreation was attendance upon the meetings and excursions of the several engineering societies of which he was an enthusiastic and liberal member.

His home life was quiet and pleasant. He was married, when about 28 years of age, to Abba S. Cole, who died July, 1893. He had one daughter, who survives him.

He was a man of pronounced individuality, active and alert, both in mind and in body, an excellent companion, clean-minded, frank, open and generous.

He became a member of the Boston Society of Civil Engineers October 15, 1884, and of the American Society of Civil Engineers October 2, 1878.

His death, which occurred August 20, 1895, in his native town of Woburn, Mass., was occasioned by heart-failure, the result of a severe attack of the grippe about two years before.

Detroit Engineering Society.

Detroit, Mich., May 21, 1897.—The regular monthly meeting was held at the Hotel Ste. Claire, Vice-President William J. Keep presiding, and twenty-four members and two visitors were present.

The Committee on Legislation submitted the following report:

To the Detroit Engineering Society:

In this report it was intended to bring certain questions of local interest before you, but through failure of our efforts to obtain copies of several bills now pending before the State Legislature we have considered it best to postpone their consideration. There are, however, two questions of national legislation which demand the consideration of the Society. The first is the duty imposed upon foreign scientific literature by the Tariff bill, now pending before Congress; the second is the bill for the adoption of

the metric system of weights and measures, also before Congress at this time. In reference to the former, your committee recommends that the Society request, through the Michigan Senators and Representatives in Congress, an amendment to said bill, admitting free of duty all scientific literature and all other literature not printed in the English language. Your committee would further recommend that the Society petition the Board of Education that the metric system be taught in the public schools.

Very respectfully submitted.

[SIGNED] DAVID A. MOLITOR, *Chairman.*

On motion, the report was accepted and referred to the Executive Committee and the committee discharged.

The following resolutions were then presented and unanimously adopted:

WHEREAS, There is now pending before our State Legislature a bill providing for manual training in the public schools of this city; be it therefore

Resolved, That this Society most earnestly endorses the purpose of said bill, and

Resolved, That the Secretary be instructed to express to the Hon. William G. Thompson, Senator from the Second Senatorial District, in behalf of the Society, a request that he use his influence to further the passage of the said bill.

The name of Thomas H. Ferguson was proposed for membership.

The Executive Committee then reported that the next meeting would be devoted to a discussion of the bill now pending before Congress providing for making the metric system of weights and measures the standard of the United States in 1900.

The paper of the evening was then read by Mr. Frederick A. Ballin on the subject, "Characteristics of Modern Yachts and Launches," and was discussed by Messrs. Cooley, Ekstrom, Molitor, Hitchcock, Mattsson, Hinchman and Ballin.

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

Association of Engineering Societies.

Vol. XVIII. JUNE, 1897. No. 6.

PROCEEDINGS.

Detroit Engineering Society.

Detroit, Mich., June 18, 1897.—Meeting held at the Hotel St. Claire, Vice-President Dow presiding and seventeen members present.

The nomination of Mr. William A. Livingstone as member of the Board of Managers of the Association of Engineering Societies was unanimously confirmed.

Mr. Thomas H. Ferguson, being reported upon favorably by the Executive Committee, was elected to resident membership.

The Library Committees presented a preliminary report and was granted further time.

The Executive Committee, reporting upon the report of the Committee on Legislation presented at the last meeting, offered the following, which was unanimously adopted:

Whereas, There is now pending before the Senate of the United States a bill to revise the tariff on imports, be it therefore

Resolved, That the Honorable Senators from the State of Michigan be requested to use their influence to secure an amendment to the said bill, admitting free of duty all foreign philosophical, scientific and technical literature not reprints or translations of American works, and

Resolved, That the Secretary be instructed to transmit a copy of these resolutions to the said Honorable Senators.

The name of A. B. Raymond was proposed for resident membership.

The society then proceeded to a discussion of the bill now pending before Congress to make the metric system of weights and measures the standard of the United States in 1900, which was opened by Mr. David A. Molitor. The discussion was participated in by Messrs. Wisner, Hinchman, Mattsson, Adams, Pope, Keep, Penton, Woodruff, McMath, Williams, Edw. Molitor, Campbell and Dow, after which the following resolution was unanimously adopted:

Resolved, That this Society most heartily indorses the bill now before Congress providing for making the metric system of weights and measures the standard of the United States in 1900.

The meeting then adjourned.

Gardner S. Williams, *Secretary*.

Engineers' Club of St. Louis.

456TH MEETING, JUNE 2, 1897.—The meeting was held at 1600 Lucas Place, at 8 P.M., with President Flad in the chair. Thirty-one members and three visitors were present.

The minutes of the 455th regular meeting and 238th meeting of the Executive Committee were read and approved.

The paper of the evening, by Prof. W. K. Hatt, of Lafayette, Ind., was then read. It was entitled "Notes on the Location of Mountain Railways." The general problems to be overcome in the location of mountain railways were first set forth, and numerous examples of their solutions were cited. The writer described the Swiss railways, and exhibited plans, sections and lantern slides showing views along the lines. Rack railways and cable railways for mountain service were described and illustrated. A large number of views were shown of the Callao-Lima Railway, of Peru, which reaches the highest point and exhibits the most difficult construction of any in the world. A general discussion followed the reading of this paper, participated in by Messrs. Crosby, Ockerson, Harrington and Hermann.

There being no further business, the meeting adjourned to the library, where lunch was served.

RICHARD MCCULLOCH, *Secretary.*

Civil Engineers' Club of Cleveland.

MEETING of the Civil Engineers' Club of Cleveland, Case Library Building, Tuesday evening, June 8, 1897, President Ritchie in the chair. Present, thirty-five members and two visitors.

The Executive Board reported the reconsideration of the resignation of Mr. John Walker and his transfer to corresponding membership.

The applications for active membership of the following were reported as approved by the Board: Charles Edgar Adams, George Isaac Allen, William Sanford Bidle, Lord Mortimer Coe, John Nash Coffin, Charles Ithamar Dailey, Ernest Winfield Hulet, Arthur Cameron Johnston, Francis F. Prentis, William Emerson Schroeder, George Edgar Titcomb and Rollin Henry White.

George Henry Kimball and John Bruce Hayden were appointed tellers to canvass the ballots for the election of new members.

Mr. Hanlon presented an invitation from the Ohio Institute of Mining Engineers to accompany them on their excursion from Sandusky to Lorain and Cleveland on the 16th, 17th and 18th of June. On a motion by Mr. Rawson, the following committee was appointed to attend to the matter: William H. Searles, chairman; W. B. Hanlon, J. W. Langley.

On a motion by Dr. Langley, the following committee was appointed to arrange for the annual picnic: Dr. J. W. Langley, chairman; F. A. Coburn, W. P. Brown, A. L. Hyde, S. T. Dodd, H. C. Thompson, J. P. Johnston.

Mr. Charles W. Hopkinson then presented the paper of the evening, entitled "The Philosophy of Architecture."

(1) The philosophical development of the desires of a people for structures.

(2) The intimate relation of a people to the resulting architecture.

(3) The development of the actual problem between client and architect.

(a) The study of the essentials of the problem.

(b) The philosophical solution of the plan.

(c) The rational development of the structure.

(d) The appropriate and logical growth of the design as a whole.

Mr. Hopkinson's paper was listened to with attention. An interesting discussion followed, in which Messrs. Searles, Barnum, Warner, Herman and others took part.

Messrs. George Henry Kimball and John Bruce Hayden were reported as elected to active membership.

The meeting adjourned and a light lunch was served.

F. A. Coburn, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, Cal., April 20, 1897.—A musical entertainment was given by the Technical Society, under the immediate direction of Mr. Hermann Barth, Director Technical Society, on the evening of April 20, 1897.

Provisions were made to entertain the members and their guests to the number of two hundred.

The musical program given below was rendered by Mrs. Hermann Barth, pianiste; Mr. H. D. W. Schmidt, first violin; Mr. H. A. T. Schmidt, second violin; Mr. Hermann Barth, viola; Mr. F. C. Hartwig, 'cello; Mr. Melville Toplitz, flute.

Recitations were also given by Mrs. C. E. Grunsky, of San Francisco, and Miss Louise Schild, of Vallejo.

At 8.30 p.m., President Molera called the meeting to order, and referred to the object of the social gathering as one intended to make the members better acquainted with one another, and to afford an opportunity to entertain the Society's friends.

The first musical number by Beethoven was then begun, and the program was most successfully carried through to the end, furnishing a most enjoyable evening.

PROGRAM.

1. Piano Quartette.................................Beethoven
2. Hungarian Dances, 5 and 6.........................Brahms
   (Strings, Flute and Pianoforte).
3. Violin Solo.........................Henry D. W. Schmidt
   a. Romance, Papini.
   b. Mazourka, Wieniawski.
4. Selections from "Faust" ....Gounod
   (Strings, Flute and Pianoforte).
5. Reading ....Mrs. C. E. Grunsky
6. Woodland Whispers, Waldesflüstern ....Czibulka
   (Strings, Flute and Pianoforte).

7. Wintermärchen ....Saro
String Quartette.
8. The Painter of Seville......................Miss Louise Schild
(Recitation).
9. Czardas—Danse Styrinne.............................Michels
(Strings, Flute and Pianoforte).

After the playing of the last number a vote of thanks was tendered to all those who took part in the rendering of the program, and the guests were invited by Mr. Percy, for the Society, to partake of refreshments that were served after adjournment.

The following ladies acted as hostesses for the Society: Mrs. Geo. W. Dickie, Mrs. C. E. Grunsky, Mrs. W. F. C. Hasson, Mrs. E. T. Schild, Mrs. Hermann Barth, Mrs. Louis Falkenau, Mrs. D. C. Henny, Mrs. G. W. Percy, Mrs. Edward C. Jones, Mrs. Otto von Geldern.

Attest.

Otto von Geldern, *Secretary.*

Regular Meeting, June 4, 1897.—Called to order at 8.30 p.m., by Past President Grunsky.

The minutes of the last regular meeting were read and approved.

The Chairman announced the election to associate membership of Mr. Adolph Greub, instrument-maker, of San Francisco.

The paper of Mr. Burr Bassell on "The Los Angeles Outfall Sewer System and Sewage Irrigation," discussed by letter by James D. Schuyler, Member Technical Society; Gervaise Purcell, A. M. I. C. E., and H. Hawgood, M. I. C. E., was received by D. C. Henny and opened for general discussion.

Discussed by Messrs. Allardt, Henny, Storey and others.

The Secretary read a paper written by Mr. James D. Schuyler, Member Technical Society, entitled "The Construction of the Hemet Dam," which was generally discussed by those present.

Mr. Henny moved that Mr. Schuyler's paper be open to written discussion, and that the paper be held until such discussions have been received before sending it to the Association for publication. Seconded and carried.

Col. George H. Mendell, chairman of committee appointed at regular May meeting, reported that the committee had waited upon Col. Charles R. Suter, Corps of Engineers, U. S. A., and that Colonel Suter had agreed to address the Society, on some future occasion, on the subject of the Mississippi River.

Adjourned.

Otto von Geldern, *Secretary.*

JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND, MINNEAPOLIS, ST. LOUIS.
MONTANA. ST. PAUL. DENVER.
VIRGINIA. PACIFIC COAST. DETROIT.

CONTENTS AND INDEX.

VOLUME XIX.

July to December, 1897.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

JOHN C. TRAUTWINE, JR., *Secretary,* 257 S. FOURTH STREET, PHILADELPHIA.

CONTENTS.

VOL. XIX, July-December, 1897.

For alphabetical index, see page v.

No. 1. JULY.

No. 2. AUGUST.

No. 3. SEPTEMBER.

No. 4. OCTOBER.

INDEX.

VOL. XIX, July-December, 1897.

The six numbers were dated as follows:

No. 1, July.	No. 3, September.	No. 5, November.
No. 2, August.	No. 4, October.	No. 6, December.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.
Names of authors of papers, etc., are printed in *italics*.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL XIX. JULY, 1897. NO. 1.

THE FIRST ENGINEER.

BY W. A. TRUESDELL, MEMBER CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

The University of Alexandria was the glory of ancient times. That remarkable seat of learning was founded in the fourth century B. C., and flourished for a thousand years. When the Christian religion grew to importance the school commenced to decay, and it was finally destroyed by the followers of Mahomet in the year 641 A. D.

Among the teachers and scholars assembled at Alexandria during this long period were many eminent mathematicians, who will be remembered as long as there is history. It was here that Euclid lived and wrote his great work. These men gradually built up the science of geometry, until at about the time of the birth of Christ, they knew as much of that subject and of conics as we do to-day. During two thousand years nothing has been added to the teachings of those old Greeks, because there has been nothing to add. They had found it all.

But while these mathematicians cultivated the science of geometry to perfection, they did it only for the sake of the study itself. They either could not or would not see anything useful or practicable in it. They objected most decidedly to the idea of removing it from the classical domain where they had placed it, and considered it vulgar and degrading to apply it to mensuration, surveying or any other practical purpose. In this they were all alike.

Finally, a very able and distinguished man appeared among

Manuscript received September 21, 1896.—Secretary Ass'n of Eng. Socs.

this group of philosophers, who departed from the accustomed methods of thought, and pursued a new line of study and for an altogether different object; who sought to find what was useful in science and to reduce it to some practical application.

This was Heron or Hero of Alexandria, who lived in that city in the second century before Christ. He was a pioneer in a new field, and his labors and their results are so unlike those of the men who had preceded him and who followed after, that he occupies a position alone and unique in the long list of Alexandrian scholars.

He was a famous character in his time, and his name is famous yet in certain departments of history. As a mathematician he was eminent among giants. In natural philosophy he was far in advance of his time, and was acquainted with facts and principles which moderns have never given the ancients credit for. As an inventor and mechanic he constructed a large number of machines and mechanical devices that have served as prototypes long after, and led to inventions of great practical importance.

The principles of land surveying were original with him. He constructed the first surveying instrument and taught how to use it. It was he who first placed surveying and engineering on a scientific basis.

This old Alexandrian scholar, who lived so long ago, was at once mathematician, mechanic, and inventor, a practical surveyor and engineer. He was the first, of whom there is any record, to labor for a system. He created a science and then brought it to useful and practical applications. For these reasons we will call him the first engineer.

We know very little of Hero's life. It is only from his writings and the works of commentators that we get our knowledge of him. It is supposed that he was an Egyptian, though he was a Greek in training, association, and education. He was the author of quite a large number of books, some of which are now lost, and several of those that are extant consist only of fragments. His principal works have been translated and printed. The originals are now preserved in the leading libraries of Europe.

Among them are three works on machines of ancient warfare, in which are described all the then known implements of that character. One work on automata describes and tells how to make water clocks and water organs, and other self-acting machines. Two others contain what would now be comprised in an elementary book on mechanics and hydrostatics. The best-known book is the *Pneumatica*, which contains descriptions and

illustrations of a large number of machines and mechanical contrivances, many of which were his own invention. Another work, the *Dioptra*, is a treatise on land surveying and leveling, where the first principles of those subjects are made known for the first time. His most characteristic work is a synopsis of elementary geometry and mensuration, where he treats of geometry in a practical manner and gives a great number of rules of application. Besides these works, there were five more on kindred subjects, which are now entirely lost. They were probably destroyed when the Alexandrian library was burned.

In the third century A. D. there was in the Alexandrian school an eminent mathematician named Pappus, who was distinguished as the author of a complete synopsis of Greek mathematics. This work is now preserved, and gives the only knowledge that is now known of the lost writings of the Alexandrian library. Pappus mentions these five lost books of Hero and gives an account of their contents, and in all probability they were as valuable as the works that are now extant.

This list of fourteen books covers the whole range of what was then known of practical mathematics and mechanical philosophy, the result of great labor and research, all written by one man in ancient Egypt, and in the second century B. C. It would be quite correct to say that practical mathematics and mechanical philosophy originated with the author of these books.

Hero was an able mathematician and learned all that the text books of that period could teach him, though he did little or nothing to extend a knowledge of abstract mathematics. He was preeminently a practical man, and was interested in science only on account of its application. If his results were true, he did not care for any theoretical reasoning by which they were obtained. He did not hesitate to add lines to areas or to multiply squares by squares, a proceeding which always raised a storm of objections. What concerned him most about any principle was, what good is it and how can it be used, and his whole life was devoted to teaching people how to use what others had found. If he made any investigation of his own or originated anything new, it was always something important and practical. The early trigonometry, in which chords were used instead of sines, had always been considered a part of astronomy, or an appendage to that science. He was the first to think differently, and to make practical applications. He attempted a solution of that famous old problem, the duplication of the cube, but only for the purpose of showing how a machine of warfare, known as the catapult, could be increased three-fold in

power. He originated new methods in numerical calculations, and used to multiply and divide in a manner which is essentially the same as we do at present. He was the first to give a methodical rule for the extraction of square roots. At that time all numerical calculations were founded on a geometrical interpretation, and no other method was countenanced by the Alexandrian philosophers. Hero persisted in using methods of his own, which, if supplied with a proper symbolism, would have been pure algebra. In his works he gives problems with solutions which require quadratic equations. This is the first record of anyone who could perform such calculations.

In his researches in natural philosophy, Hero was the greatest of all ancient scholars. That subject had received but little attention before his time. He experimented and wrote on the elasticity of air and of steam. He was acquainted with the pressure of fluids, and wrote on hydrostatics and hydraulics. He explained how to find the center of gravity of the different geometrical figures and solids. From what was then known of motion and force, he deduced the five mechanical powers, the lever, wedge, screw, pulley and wheel-and-axle, and called them by names corresponding with those used to-day. He afterwards discussed at length the problem of moving a given weight with a given power, and showed how to unite and combine those mechanical powers in different ways, so as to get the best results. In his books on war engines, he explains the construction and principle of those machines, and gives suggestions how to increase their power and effectiveness.

But Hero's reputation as a practical man is still greater when his achievements as a mechanic and inventor are considered. The best-known and the most interesting of his books is the *Pneumatica*, in which he describes and illustrates over one hundred machines and mechanical contrivances, some of which are exceedingly ingenious. He states that he is the inventor of most of them, but does not specify these. It is probable that, as he constructed them, they were only intended for models to illustrate his experiments and researches.

One of the machines described in the *Pneumatica* was called the Fountain, and is a familiar object to those who remember the old text books on natural philosophy. By this contrivance air is condensed in a chamber by means of a column of water, and the air, in turn, raises another column to a height equal to that of the condensing column. This is the oldest pressure engine known, and it has been imitated in modern times. A machine very much

similar and acting on the same principle was once employed to raise water from a mine in Hungary, where it was long celebrated. By means of a spring 140 feet above the mouth of a shaft, water was raised from the bottom, 104 feet, to the top, and the mine was thus drained.

Another remarkable machine described and illustrated in the *Pneumatica* is a fire engine, invented and constructed by Hero himself. This was founded on the principle of atmospheric pressure, and did not differ in its essential parts from a fire engine of modern construction. It consisted of two brass forcing pumps, each with a valve and piston connected to one discharging pipe. The pistons were worked by a double lever. The two pumps were secured to a wooden base which was partly immersed in water, and the whole arrangement was mounted on a sort of carriage. The discharge pipe, into which the water was pumped, terminated in an air-chamber, and from this chamber the water was forced through another pipe, which could be turned in any direction by means of a swivel joint. The principle of the whole machine, the two pumps, pistons, valves and air-chamber, the outlet and inlet pipes, was the same as employed in engines of like character in modern times.

In the *Pneumatica* we have also an account of the first steam engine ever known. It could not have been of any practical utility, but it was the first instance where motion was produced by steam. This, also, is a familiar object, and has often been described and illustrated. It consisted of a hollow sphere furnished with two arms at right angles to its axis, and bent in opposite directions at the ends. The sphere was suspended between two upright columns, which were bent at their extremities. One of them was hollow, and through it the steam passed from a boiler below to the sphere, and the escape of the vapor through the small tubes produced a rotary motion. The principle employed in this ancient contrivance has been patented in Europe no less than six different times, and that early effort of Hero has been developed into machines of great usefulness. It was a forerunner of the primitive Barker's water mill and the modern turbine.

Another apparatus described deserves mention, because it was the prototype of a class of engines that became long afterward practically important. This was a heat engine, in which expanded air, by means of fire, was made to open and close doors, and was used in temples, theatres and other public buildings. This was the first step toward what is now the modern steam engine. Eighteen hundred years after a machine working on the same principle, but

with steam instead of air, was patented in Europe by Thomas Savary, and was used for pumping water from mines in England and Scotland until the beginning of the present century.

In the *Pneumatica* more than twenty different forms of the siphon are described, or rather that many different methods of using the instrument are illustrated. Hero explains how it can be employed to drain or irrigate land, by conveying water a long distance over hills and valleys. From him we learn that it was extensively used at that time to irrigate lands bordering on the desert.

The *Pneumatica* was much sought after and studied during the sixteenth century by mechanics, engineers and all others engaged in mechanical research. It was a veritable feast to men like Fludd, Porta and Galileo, who made great use of it, the former without any acknowledgment.

Hero's principal and most characteristic work is his practical geometry and mensuration. This was the first effort to use geometry for practical purposes, and was in direct opposition to the teachings of the Alexandrian school. He gives a large number of rules and formulas, usually without proof, for finding the areas of all geometrical figures, from triangles to segments of the circle, also polygons of any number of sides, and fields of different shapes and with irregular outline, and then tells how to find the height of an inaccessible object. Afterwards, rules for finding the volumes of all the different solids, and then shows how they can be made useful in the practice of architecture, such as theatres, halls, baths, etc. The book concludes with a table of weights and measures.

The most interesting to us of all Hero's books is the *Dioptra*, which is, in reality, a treatise on land surveying. It is the first book ever written on that subject, and is a collection of the earliest rules and principles ever used by any surveyor. Hero was, without any doubt, the originator of systematic surveying and leveling.

First, there is a description and illustration of the instrument called the dioptra, which was the original transit or theodolite and level. The greater part of the book consists of thirty-three problems, most of them relating to surveying and leveling, with their solutions by aid of this instrument.

The dioptra, as it is described and illustrated by Hero, was constructed in the following manner: The whole instrument, with the exception of a glass water level, was made of brass, and was about five feet high. The lower part or support was a hollow cylinder about three feet in length, with three sharp prongs at the bottom to hold it firmly to the ground, and a small weight was suspended by a string at one side, to show when it was vertical.

On top of this support a large circular plate was fastened, always in a horizontal position when the instrument was in use. Above this was a second hollow cylinder less than a foot in length, and enveloping a spindle of the same length, which was fastened to the large circular plate. The bottom of this second cylinder was a cog-wheel, of a diameter less than that of the circular plate on which it rested, and the top, by way of ornament, was finished off like a Doric column, with a square capital on top. A long screw was fastened to the circular plate by two pins and tangent to the

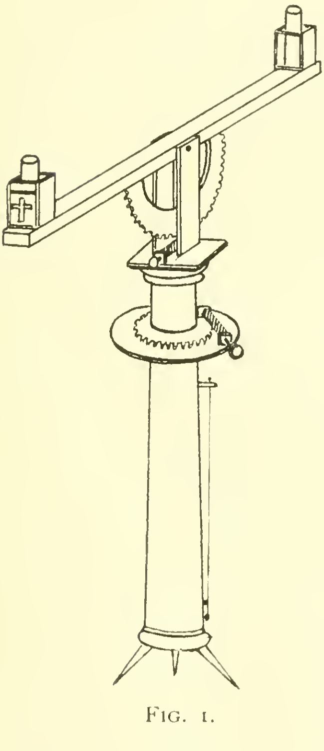


FIG. 1.

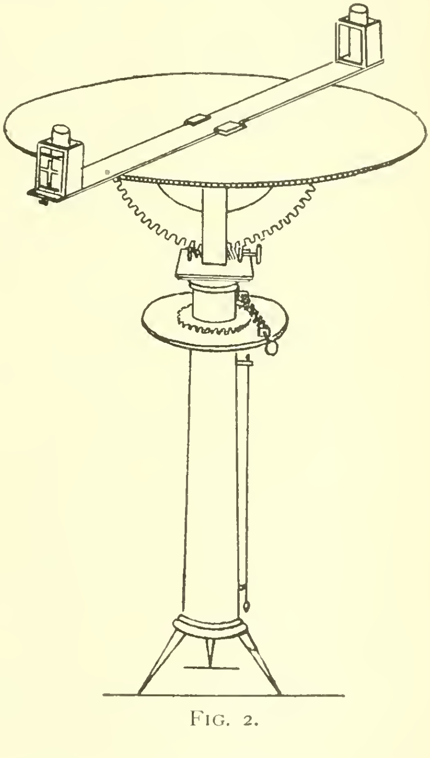


FIG. 2.

cog-wheel. By turning this screw all of the instrument above the circular plate could be revolved in a horizontal direction around the stationary spindle. Above the square capital were two vertical blades or standards, about a foot long, and between them, at the

Fig. 1 represents the dioptra as it is described and illustrated by Hero, but some of the problems which he gives required an instrument of somewhat different construction. These are Problems 16, 17 and 28. In the original manuscript there is a blank space, which is supposed to have been meant for another illustration. Fig. 2 is this illustration, as restored by Venturi, an Italian commentator.

top, was a rule or straight edge, six feet in length, and hung to them by a pin or journal, to allow a movement of the straightedge in a vertical plane. Below the straightedge, and between the standards, was a vertical semi-circle, cogged at its outer edges and turned by a long screw fastened to the square capital. On top of the straightedge a long water level was placed, and at each end was a thin blade with a slit cut in it, through which the observer could look.

The dioptra could be used for staking out straight lines or for leveling. To lay off a right angle, two little points or marks on the large circular plate were used. The upper cylinder was placed first at one of these marks, and a line was set on the ground. The cylinder was then turned to the other mark by the lower tangent screw, and thus gave a line at right angles to the first. For leveling, it was only necessary to bring the straightedge to a horizontal position by the upper tangent screw.

Hero also describes what he calls two poles, which were used with the dioptra, either as leveling rods or as pickets; that is, one for a foresight and the other for a backsight. Each of these poles was about fifteen feet long, four inches wide, and two and one-half inches thick. In the middle of one side, and for the whole length, a dove-tailed groove was cut, and in this a tenon was placed so as to move easily. On this tenon a circular target, nine inches in diameter, was fastened, one-half painted white, the other half black. A cord tied to the target ran over a grooved wheel at the top of the rod, and could be tied to a pin on the back of the rod. The target was raised by this cord and lowered by its own weight. The rod was divided into cubits, palms and digits, commencing at the bottom. To hold the rod in a vertical position, a small weight was suspended by a cord from the end of a short pin at the top.

The dioptra was the only surveying instrument known for a very long period. It was introduced into Rome, where it was extensively used by the Roman surveyors for at least five or six centuries, both as a transit and as a level. While the Empire was at the zenith of its power, the Romans carried on quite a large system of improvements. They were great surveyors, great map makers, and, in a practical way, great engineers. In the construction of their military roads, arch bridges, harbor improvements and extensive aqueducts, all the necessary instrument work was done with the dioptra in the same manner that Hero had taught.

The circular plate on the dioptra was not divided into degrees, and only right angles could be measured with it. It does not appear that the graduated circle was ever used in ancient times.

For measuring angles at that time the cross staff was used. This was seldom required, and then mostly for astronomical purposes. It is probable that in surveying, angles were determined by chords. In the latter part of the fifteenth century, when trigonometry had become something of a science, one quadrant of the circle was divided into degrees, and some years later the opposite quadrant was graduated, to give the benefit of a second reading. About one hundred and fifty years after this, or in 1631, the vernier was invented and added to the instrument. It was only about one hundred and thirty years ago that the whole circle was graduated for the first time.

The following problems are all contained in the *Dioptra.* Each solution is written out at length, and every operation is explained in detail in Hero's book. A very brief outline only of these solutions is given here. The figures are exact copies of the originals, except the lettering:

(*1*) *To find the difference of level between two points.*

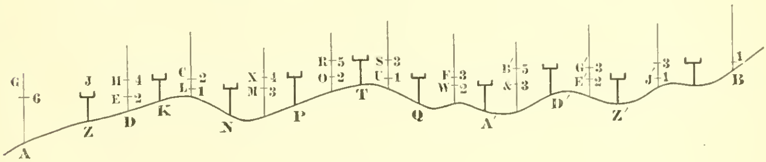


FIG. 3.

The solution of this problem is similar to those given in modern text books. A supposed case is illustrated, and the author gives very minute directions about placing the dioptra and leveling rods at each successive stage of the operation.

The backsights he enters in a column marked "down," and the foresights in one marked "up," and after adding the two columns he takes the lesser sum from the greater for the difference of level. He concludes with some remarks about the usefulness of this process in conducting water from any place to a lower one, and around intervening elevations and depressions.

(*2*) *To run a line from a given point to a second point which cannot be seen from the first.* (Fig. 4, page 10.)

Hero's solution of this problem makes a modern surveyor think of latitude and departure. His process is, in reality, an application of that method.

Let A and B be the two given points. Connect them with the dioptra by several different lines, making each line of any convenient length, and at right angles to the one preceding it. Write the lengths and add them as follows:

A G = 20 cubits.	G D = 22
D E = 16 "	E Z = 30
— Z H = 14 "	H C = 12
C K = 60 "	K L = 8
— L B = 50 "	—
—	72
32 "	

This gives A M = 72 cubits and M B = 32 cubits. Measure on A M any distance A T = 9, and make 72 : 32 : : 9 : T U = 4. Also measure U F any distance, say 18 cubits, and make 72 : 32 : : 18 : F Q = 8. Continue this operation and get U, Q, etc., points on the required line.

(3) *To measure the horizontal distance to an elevated distant point without approaching it.* (Fig. 5.)

Let B be the distant point. With the dioptra at A, mark the point G and lay off the perpendicular A D, also G E of any con-

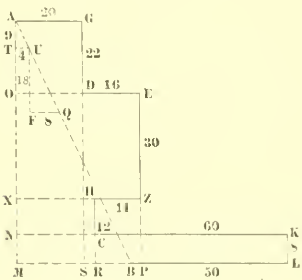


FIG. 4.

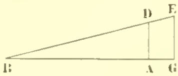


FIG. 5.

venient length. With the instrument at E, mark the point D on line with B, and measure A D and A G.

Then the required distance A B will be that part of B G that A D is of E G. It will then be known what part A G is of B G or of A B, and the latter line can be easily determined.

(4) *To find with the dioptra the width of a river, remaining on one and the same side.*

This problem is merely a continuation of, ro an application of, the preceding one. It was long afterwards a favorite with the military engineers attached to the Roman armies, and was called by them a problem in strategy.

(5) *To measure the horizontal distance between two distant inaccessible points.*

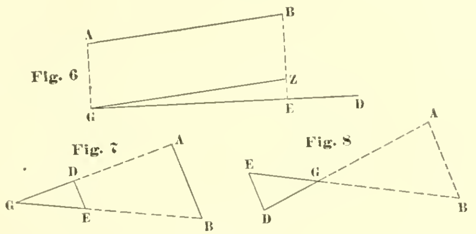
First solution. Fig. 6. Let A and B be the two given points. From any assumed point G, lay off G D at right angles to A G.

Set the dioptra at E so that E B will be perpendicular to G D, and by problem 3 find A G and E B. Measure the difference of these distances E Z on E B. Then G Z will be parallel and equal to A B, and can be measured on the ground.

Second and third solutions. Figs. 7 and 8. From the assumed point G, calculate A G and G B by problem 3. Lay off G D equal to one-tenth of A G, and G E equal to one-tenth of G B. Measure D E, which will be one-tenth of A B.

(6) *To lay off on the ground a perpendicular to an inaccessible line at one of its extremities.* (Fig. 9.)

Let A be one extremity of an inaccessible line A B. Hero's solution of this problem is to lay off a line G D parallel to A B by problem 5, and then by trial to find the point E, so that a perpendicular E A to G D will pass through the point A.



FIGS. 6, 7, 8.

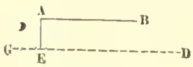


FIG. 9.

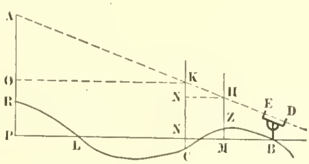


FIG. 10.

(7) *To measure the vertical height of an inaccessible point.* (Fig. 10.)

Let A be the elevated point, B Z C L R the surface of the ground, and B P the plane of the horizon at the point of observation B. Calculate the horizontal distance B P by problem 3. Set two pickets H Z and K C so that their tops are in line with A. By leveling, find Z M and N C. Then we will have H M and K N. Measure H X, and K O will be known. By similar triangles A O is found, and this added to K N gives A P the height required.

(8) *To measure the difference of heights of two inaccessible points.*

(9) *To measure their distance apart.*

(10) *To determine the position of a line which joins them.*

(*11*) *As an application, to measure the height of a mountain.*

The solutions of these four problems are merely a continuation and application of the preceding ones, especially of problems 3, 5 and 7. Problem 11 consists of remarks and directions about measuring and locating the different points on a mountain.

(*12*) *To measure the vertical depth of an excavation.* (Fig. 11.)

Let A D O be the horizontal plane. With the dioptra at E, set two rods K N and X M with their tops on line with the point B at the bottom of the excavation. Measure A O by preceding methods, also K M, and by leveling K S and M O. By the two similar triangles X N R and X B P, X P can be found, and as X O is known, O P or its equal A B is known, which is the vertical distance required.

(*13*) *To cut a tunnel through a mountain from one given point to another.* (Fig. 13.)

Let A B G D be the base of the mountain, and B and D the two points. Run the lines B E, E Z, Z H, etc., each one at right

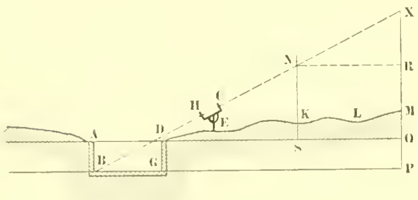


FIG 11.

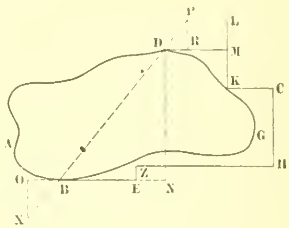


FIG. 12.

angles to the one which precedes it, to K L. On K L find the point M, so that a perpendicular to K L will pass through D. Find B N and N D the same as in problem 2. Lay off O B X and D P R each similar to B N D. X B will give the direction at the portal B, and P D at the portal D. The author adds that "to insure the success of the operation, it will be necessary to plant a picket at some point in X B and P D produced, so that the workmen will finish by meeting each other."

(*14*) *To sink vertical shafts to meet a horizontal tunnel.* (Fig. 13.)

G A B D is the line of the tunnel; the portals at A and B. Place the instrument at H on line with two pickets at G and A. Move the picket at G, and place it on line at M. Then carry the dioptra to X on line with the pickets at A and M. Move the picket at A and place it on line at O, and so on. This will give points like M and O for shafts, directly over the tunnel.

The author says, in addition, "that for correctness, these points should also be established from the line B D."

Problem 15. *Having given a crooked subterranean gallery, to find on the ground above a point from which to sink a shaft to a given point in the gallery.* "So that material for construction may be lowered, and the debris removed in case a crumbling place is reached." (Fig. 14.)

In the given solution two shafts are already excavated. A B D G E is the gallery, and M the required point. A plumb line is lowered in each shaft and the two points P and X marked on the floor of the gallery. On the line P X S a series of triangles are measured off, so that a side of the last one will pass through the point M. These triangles are then laid off on the ground above and the point V is located, from which a shaft would reach the given point M.

Problem 16. This consists of directions, showing how to locate and draw the shore lines of a river or harbor. Problem 17 explains how to throw up or grade any given area of ground in the form of a spherical surface, and Problem 18 how to grade or slope a piece of ground of any shape to a given inclination.

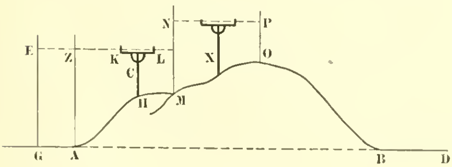


FIG. 13.

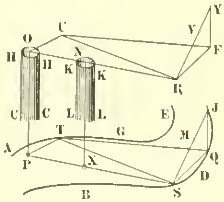


FIG. 14.

(19) *To measure in a given direction any given distance.* (Fig. 15.)

This problem reminds one of stadia surveying. The dioptra is set up on a level piece of ground, with a vertical rod a short distance away. Opposite to the rod, distances are measured off on the ground. Marks are now made on the rod where lines of sight strike it, which pass from the points on the ground through both eye-pieces of the dioptra. In this manner the rod is graduated, and may be used with the dioptra to lay off any length, or to measure to an inaccessible object, always placing the rod the same distance from the dioptra that it was when graduated.

(20) *From a distant inaccessible point, to lay off a given distance in a given direction.* (Fig. 16.)

A is the given point, B the dioptra. Find A B according to problem 3. On A B take B G, which may be any part of it. Lay off D G parallel to the given direction by problem 5, and make it the same part of the given distance that B G is of A B. Produce

B D and make B E the same multiple of B D that A B is of B G. A E will be the required line.

(21) To measure the area of a field of irregular shape. (Fig. 17.)

In the field a rectangle is laid out, having three of its corners in the irregular boundary. From the sides of the rectangle offsets or ordinates are taken to the boundary, at certain intervals or whenever necessary, and dividing into triangles and trapezoids the field outside of the first rectangle. From these data the area is calculated by finding the sum of all the interior figures.

A second solution is given where the boundary is made up of straight lines. The field is divided into triangles and trapezoids.

(22) To restore lost corners of a field. (Fig. 18.)

A field with an irregular boundary is given. In the first

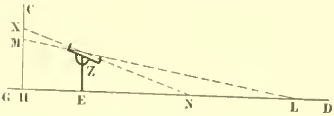


FIG. 15.

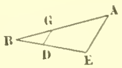


FIG. 16.

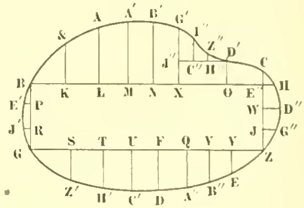


FIG. 17.

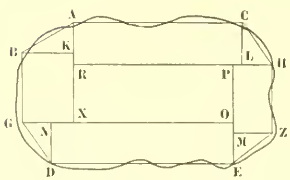


FIG. 18.

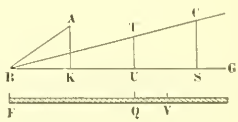


FIG. 19.

place, to represent on paper a plan of this field. The irregular boundary is determined by straight lines, drawn so that those marking the ends of the field will be at right angles to those which determine the sides. The interior is then divided into triangles and rectangles. The lengths of all the sides of the interior figures are measured and marked on the plan. In a field, represented by the above figure, all the boundaries except the points B and C are gone. It is required to restore the lost corners on the ground, for example, the one at A. (Fig. 19.)

Measure in the field a line from B to C. B G is supposed to be parallel to the longitudinal lines of the field, though not yet determined on the ground. Take B T any part of B C and in the

triangles B T U and B C S, B S and C S are known from the plan, and B U and T U can be calculated by proportion. Mark on a chain F Q equal to B U, and Q V equal to T U, and with the end F at B and V at T, stretch the chain and Q will give the point U, which will locate the line B G on the ground. On B G lay off B K according to the plan, and erect K A perpendicular to B K. This will re-establish the corner A. This is as far as the solution goes, but it concludes with the remark that all the other corners can be restored by processes similar to the one here explained.

(23) *To divide a field into given portions by lines starting from the same point.* "Suppose, for example, that the given point is a reservoir of water, which all the owners of the field are to use." (Fig. 20.)

Calculate the area of the whole field. It is required to divide it into seven equal parts by lines starting from M. Take the triangle A M B and find its area. If more than one-seventh of the whole field, find the triangle B M X equal to the surplus, and

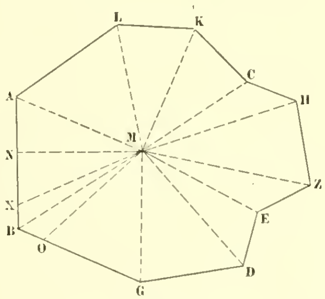


FIG. 20.

then A M X will be the first required part. If A M B is less than one-seventh, find B M O equal to the deficiency, and then A M O is the first seventh part. In the triangle B M X, to find B X we have the area and the altitude M N, from which B X is easily found. Operating in the same manner on the other triangles, the whole field will be divided into seven equal portions.

(24) *To measure a field without entering it*, "by reason of thick vegetation or because it is not permitted to enter it." (Fig. 21.)

A B G D, etc., is a given field. Prolong C H to L and Z H to K, so that H K is the same part of H Z that H L is of H C. Then from K L we can find C Z, and from the triangles K H L the triangle C H Z can be found. K L is parallel to C Z. C may not be visible from Z. Prolong H Z and make Z M equal to H K. With a chain equal to K L plus L H, and with its ends at Z and M, mark the point N on the ground. This will give C Z produced.

Prolong E Z to X, so that Z X is any part of E Z, and make Z O the same part of C Z. This will give Z X O a triangle similar to C Z E, and the area of C Z E can be obtained. In the same manner calculate the areas of the remaining triangles, from which the aıea of the whole field can be found.

(25) *To divide a trapezoid by a line parallel to its base.*

The inclined sides of the trapezoid are produced to an intersection, and the similar triangles so formed gives, by proportion, the length of the required dividing line and its position.

The method of finding the area of a triangle from the three sides was original with Hero. He gives an ingenious proof, and works out an example where the sides are 13, 14 and 15. This is problem 26 of the *Dioptra*.

(27) *To measure the quantity of water flowing from a spring.*

"In times of rain the flow augments, caused by the super-

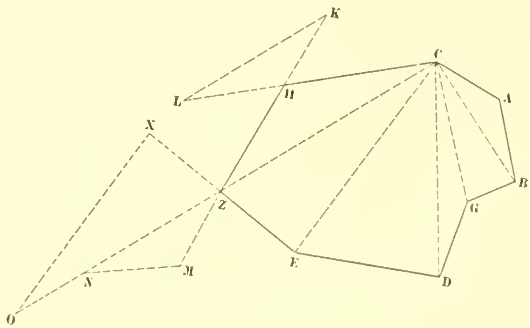


FIG. 21.

abundance of water which comes from the mountains, and spouts up with great force. It diminishes, on the contrary, in times of drought, because enough water does not reach it to feed it. Make a conduit in the form of a quadrangle, then adapt it to the spring in such a way that all the water is forced to enter it. Take, then, at the end of the conduit the water which runs out. Suppose it is two digits high and the width six digits. This will give a section of flow of twelve digits." Then, by ascertaining the velocity of the current with a sun dial, the amount of flow in an hour can be determined. A better method, the author adds, is to dig a reservoir and let the water run into it for one hour and then measure the amount of water.

(28) *To measure the angular distance between two fixed stars.*

This requires an instrument somewhat different from the one described by Hero. There is a large circular plate on which the

rule revolves. The outer edge of the plate is divided into 360 degrees, and the rule is capable of being removed entirely from the plate. After removing the rule bring the plane of the plate in the line of the two stars and clamp it. Replace the rule and direct the sights to one of the stars, and by means of a pointed index on the rule note the reading on the circle. Turn the sights to the other star and note the reading. This will give the number of degrees between the two stars. Whether this was really ever accomplished or is merely a suggestion does not appear. At any rate, it is the first mention made of a circle being graduated into 360 degrees.

(*29*) This problem is a criticism on the asterisk, an instrument in use at that time to a limited extent. Hero attempts to show the superiority of his dioptra, as constructed by himself, over the asterisk for practical use.

(*30*) This is a long description of a contrivance called an odometer. It comprised a series of cog-wheels attached to a carriage, and so arranged as to move a pointer on a measured dial, and thus indicate the distance traveled. There is an illustration also given.

(*31*) *To ascertain the speed of a ship.*

Another odometer, consisting of four cog-wheels, is illustrated and described. A paddle-wheel is secured to the side of a ship, and the motion of the vessel through the water causes the wheel to revolve. The wheel, in turn, moves the cog-wheels, and a pointer on a dial indicates the distance the vessel travels.

(*32*) *To determine the distance between two places on the earth's surface,* as, for example, from Alexandria to Rome, "following the circumference of one of the great circles."

Hero works out this problem substantially as follows: The circles of a celestial sphere are drawn, with a latitude equal to that of Alexandria. By means of an eclipse of the moon, he determines the difference of longitude. This, he says, can be taken from the "Register" or can be determined by observation. This difference of longitude locates the meridian of Rome on the sphere, and the latitude of that city, which he determines, locates the zenith of the horizon at Rome. A great circle is then drawn through this point and the zenith of Alexandria. The angular distance between these two points he determines mechanically and finds it to be 20 degrees. About one hundred and fifty years previously, Eratosthenes had found the circumference of the earth to be 252,000 stadia, or 700 stadia for one degree. Hero says the required distance is 14,000 stadia.

(33) *With a given power, to move a given weight by means of a system of cog-wheels.*

It is explained and illustrated in the solution of this problem how to construct four cog-wheels, turned by a crank, so that one man, exerting a power of five talents, can lift a weight of a thousand talents.

In these problems, Hero made no use of trigonometry. That science had been invented just before his time, and at first there was very little of it. There was in existence a single table of chords, by which both plane and spherical triangles could be calculated. But this was considered an inseparable part of astronomy, and even in that science very little use was made of it. Sines, co-sines and tangents were not invented until a thousand years later. Hero, however, was the first to perceive the utility of trigonometry and to make a practical use of it. By means of it, he calculated rules for finding the areas of regular polygons of from five to twelve sides, and these are the rules which can be found to-day in any text book in mensuration.

Hero was the first to place the art of surveying on a correct foundation. He was a scholar, an investigator and a teacher. He was the originator of practical mathematics. He was the first engineer, in the same sense that Thales was the first geometrician, Hipparchus the first astronomer, or Galen the first physician. He collected all the isolated facts and fragments then known relating to his special subject, added to them by his own researches and endeavored to bring them together in one comprehensive body, for it is now conceded by competent authority that all his books, now in disconnected fragments, were originally one complete work containing all the knowledge necessary for surveyors, mechanics and architects in the practice of their vocations.

The works of Hero, owing to their practical character, were much sought after and were extensively used by the people of the surrounding nations. Like all other works from the Alexandrian school, they were known in India and Arabia, but the greatest field for their usefulness was among the Romans. Hero's practical geometry and surveying comprised all the mathematics ever known in the Roman Empire. Hero was a teacher of the Romans. They afterwards elaborated his methods of surveying, and in time carried that art to great excellence. They cared nothing for the abstract geometry of the Greeks. They were no investigators, and in all Roman history there is no mention of a mathematician of any note whatever.

In the special line of work in which Hero was distinguished

no one followed him to complete what he began. His successors in scientific ability fell back either on astronomy or the well-worn subject of geometry. The Alexandrian school continued to exist for eight hundred years longer. On its destruction, in 641 A. D., the Greek scholars who were then living there fled to Constantinople, and carried with them what books they could save from the wreck of the library, which the early Christians had ruined, and which the Arabs finally destroyed.

A very long time after this, or in 1453, the Turks besieged and captured Constantinople. The Greek scholars who escaped the slaughter fled to Italy and carried with them the remnants of the Alexandrian library, which had been preserved in Constantinople for eight hundred years, and for the first time the people of Europe came into possession of the remains of that storehouse of learning which had been built up in Alexandria many centuries before.

HIGH GRADE STEEL.

By J. C. Danziger, Member Detroit Engineering Society.

[Read before the Society, June 19, 1896.*]

PROCESSES OF STEEL MANUFACTURE.

The leading processes by which steel is made are, in the order of their importance, (1) the Open Hearth, (2) the Bessemer, and (3) the Crucible; or, in chronological order, (1) the Crucible, (2) the Bessemer, and (3) the Open Hearth. Several conditions are tending daily to increase the importance of the Open Hearth process. By this process phosphoric ores may be successfully handled and ingots of the largest size produced. It enjoys more of the confidence of engineers than does the Bessemer, and its product is cheaper than crucible steel.

Briefly reviewed, these processes are as follows:

In the Bessemer process the molten iron is poured into the converter, which is a pear-shaped vessel, lined with a basic or an acid refractory lining, as the process is to be basic or acid. The carbon and silicon of the bath are, as far as possible, burned out by a blast of air through the iron, and the bath is then recarburized to the required amount with molten pig or spiegel. If with the former, ferromanganese is added to furnish manganese to the bath and to combine with the sulphur and the superfluous oxygen, and the steel is then ready for the moulds.

In the Open Hearth process, the pig is melted down in a reverberatory furnace, either basic or acid lined, and the carbon and silicon are removed by adding a pure oxide of iron (ore) to the bath. The reduction is carried only to the desired point, and no effort is made to burn out all the carbon with a view to recarburizing, as in the Bessemer process. Ferromanganese is generally used to impart manganese and carbon to the bath.

Oxide of nickel, ferro-silicon, etc., are also used in certain cases to obtain special results. The metal is then ready for the mould. The points of difference between these two processes are: the much longer time occupied by the Open Hearth, the larger charges, perfect control, and the frequent analyses.

The Crucible process is of minor importance, the steel being used only for cutlery, files, saws, and other tools. There is little doubt that much of this ware, stamped "Warranted Cast Steel," or,

* Manuscript received June 26, 1897.—Secretary Ass'n of Eng. Socs.

"Warranted Crucible Steel," is in reality made of select Open Hearth, or even Bessemer, and is perhaps the better for it.

Bessemer steel is looked upon with not a little disfavor at present, for higher grade purposes. Many engineers consider it too unreliable and irregular to be used in construction, where there is any close estimating for strength. This feeling is not without good foundation, but the usual method of manufacture is responsible for it, and not the principle upon which the process is based. The modern high speed of production results in many irregularities, which, with care, could be avoided. The Open Hearth bath is always melted down from select pig-iron, but the Bessemer converter must be content with the direct metal, drawn off from the blast furnace or mixer, dumped in and blown without the composition of the iron being under certain control. Of course there is an effort to keep the furnace on an iron of a certain silicon, also to control the sulphur, but this is not always possible. There is no reason, except the additional expense, why the blast furnace metal should not first be cast into pigs, analyzed, graded, charged into a cupola furnace and remelted before going to the converter, and this indeed is sometimes done in making certain high-grade steel rails.

The length of the blow has also been much reduced. Formerly, if fifteen minutes were used to blow a seven-ton charge, it was thought good practice. Iron of two per cent. silicon was charged, necessitating a blow of that length. The more modern way is to make the blow in from eight to ten minutes. This necessitates rapid blowing, in order that the 1 to $1\frac{1}{4}$ per cent. silicon may furnish fuel enough to keep up the heat. This rapid blowing, combined with the imperfect control of the composition of the bath, resulting from the use of direct metal, causes the too frequent occurrence of heats which are either too hot or too cold. I do not doubt that, with the proper care, the Bessemer process can be made to yield a medium steel in every way as good as that produced by the Open Hearth.

The Open Hearth process is the only one to use when very large ingots are to be produced. At Bethlehem, and probably at Homestead, ingots are made of upwards of eighty tons weight. On account of the perfect control, the ample time and the frequent analyses, steel of any composition can be produced. All the various steel alloys of iron, with the other members of the iron group, are best produced in this way.

In conversing with some engineers, especially in the West, the writer has found a lurking prejudice against steel. The cause is not far to seek. Wrought iron will submit to all kinds of abuse

of work and heat treatment and show no bad effects. Steel, however, quickly resents the bad handling of ignorant operators. Iron, with its low elastic limit and loosely welded mass, remains, with some, the favorite material, simply because the finer metal is begrudged proper handling.

PHYSICAL PROPERTIES.

The physical properties of steel may be varied by the chemical composition, by the fabrication under hammer, press, or rolls, and finally by the subsequent heat treatment.

The points usually noted in the physical test of steel are: tensile strength, elastic limit, extension, contraction of area, and fracture. To these, for some purposes, is also added the modulus of elasticity. Users of structural steel have long demanded definite qualities in their specifications, but users of steel forgings, which should be of much finer and higher grade steel, are only beginning to ask for definite qualities. The writer has frequently noted the growth of these specifications. Consumers begin by asking for a definite tensile strength. In their next specifications they add extension. Elastic limit is the next addition, and, finally, contraction. In the gun work for the U. S. Army, the elastic limit and extension are considered the most vital points, and, after them, the contraction of area. The tensile strength is considered of less importance. The modulus of elasticity of every test specimen is obtained. This is certainly rational, as, for most purposes, a material is useless after being strained beyond the elastic limit and permanently distorted. The contraction of area is a much neglected qualification, yet there is good reason to believe that it bears a direct relation to the shock-resisting power of steel. Frequently a steel of excellent extension, but low contraction, shows a coarse grained fracture and a rough skin after breaking; but invariably a heavy contraction, even when accompanied by little extension, is associated with a silky grain, or a fracture of minute facets, like points of pins.

The endurance of steel under the drop, and under alternate transverse tension and compression, is of the first importance, but the ordinary tests are so much more readily made, that, except for special purposes, the others are never required. The drop test is made the chief test for certain work, but the test of endurance under alternate strains, or the fatigue test, consumes so much time that it is at present impossible to use it commercially. The only practical course would be to determine, by a series of tests, exactly what relation the endurance bears to the ordinary physical properties, and to base specifications upon these results.

THE EFFECT OF CHEMICAL COMPOSITION.

We have next to consider the effects of the various chemical elements upon the physical qualities of steel. Carbon is, of course, the first to be considered, and its effect upon steel is the best known. Every user of steel has studied the varying effects of carbon, and is more or less acquainted with them. Many attempts have been made to construct formulæ and scales showing the effect of increments of one-hundredth of one per cent. of this element on the tensile strength, but these have met with little success. The weight of evidence indicates that the carbon and tensile strength curve is a straight line, but what its exact equation is, and how it is affected by the presence of the other elements, is hard to determine definitely. The view that the tensile strength is increased by eight hundred to one thousand pounds per square inch by the addition of one-hundredth of one per cent. of carbon, has received considerable support, and is probably very near the right figure. All such calculations must be based upon the tensile strength of absolutely pure iron. This has never been definitely determined. It is well known that carbon gives to steel its peculiar properties of hardening and annealing under heat treatment.

The study of the exact variation of structure which brings about this change is now attracting much attention. The physical conditions are studied microscopically, as follows. A section of steel is carefully ground with emery of the various grades, down to the finest, then with crocus, and finally with the best washed rouge. The surface is then etched with dilute hydrochloric acid and examined or photographed under a microscope, enlarging from thirty to two hundred diameters. Märtens, Sorby, Osmund and Wedding, in Europe, and Howe, Dudley and Sauveur in this country have done much good work in this direction. Steel of all percentages of carbon, and in all physical conditions, has been examined, but nothing positive has as yet been determined.

This much, however, is certain; that there are three constituents that go to make up steel. These are called by various names, but the nomenclature of Howe is generally accepted in this country. He calls them Ferrite, Pearlyte, and Cementite. The first is free, pure iron; the second is of disputed composition, and the third is unquestionably rich in carbon and perhaps a definite carbide.

It is the variation of these three substances that produces the varying physical properties under different work and heat treatment. The effect of carbon is, in a general way, to raise the tensile strength and the elastic limit, to lower the extension and the

contraction, and to change the fracture from silky to dull gray or crystalline. It probably has little, if any, effect upon the modulus of elasticity. In the examination of nearly 20,000 specimens of steel, under every variety of treatment and composition, all turned and polished bars with screw ends, and fully 5000 of these for modulus, with electric contact micrometers, the writer has never noticed that varying the percentage of carbon has any effect upon the modulus of elasticity.

Manganese is next in importance to carbon in controlling the physical qualities of steel. It is primarily added to both the Bessemer and the Open Hearth baths to combine with the sulphur and oxygen, so that these objectionable elements may be drawn off in the slag. Undoubtedly, manganese has, of itself, a counter-effect to sulphur and its presence reduces the red-short effect of that element. Manganese tends to lessen the blow-holes, and its presence results in a sounder casting. The presence of manganese undoubtedly raises the tensile strength and the elastic limit of steel, but it is a question whether it does so by negativing the sulphur and lessening the blow-holes, or, whether it is, of itself, a hardener. It is generally assumed that manganese does harden steel, but its effect varies with the percentage of carbon present, and has about one-third the effect of an equal percentage of carbon. Proportionally, manganese raises the elastic limit much more than it does the tensile strength. The following specimens were cut from one inch rolled bars and annealed at 1000° Fahr., in order to bring them all into about the same physical condition. They were then turned accurately to a shaft ¼ square inch in area with enlarged screw ends. The elastic limit was determined with an electric contact micrometer. Unless otherwise noted, the experiments were made by the writer.

	Carbon.	Manganese.	Phosphorus.	Sulphur.	Silicon.	Tensile Strength.	Elastic Limit.	Extension.	Contraction.
(1)	.499	1 25	.059	.090	.279	126,000	73,000	15.25%	41.05%
(2)	.585	.58	053	.089	.117	106,000	56,000	15.25%	31.42%

It will be noticed that the percentages of phosphorus and of sulphur are practically the same in both cases. The carbon in (2), is almost one-tenth of one per cent. higher than in (1), yet (1) has 20,000 pounds (about 20 per cent.) more tensile strength, 17,000 pounds (about 30 per cent.) more elastic limit, 30 per cent. more contraction of area, and a fracture of much finer grain. There

seems to be no explanation of this, except that it is due to higher manganese and silicon, or to some combination of the two. It is of interest to note here that these elements are looked upon with disfavor by some engineers. The higher elastic limit relatively to the tensile strength, accompanied, as it usually is, with a greater contraction relatively to the extension, indicates that this steel is well adapted to resisting shock.

When the quantity of manganese is between 3 per cent. and 5 per cent., it is very hurtful to steel, but when it reaches 7 per cent. to 20 per cent. there results an entirely new and curious steel, called "manganese steel." It is not within the scope of this paper to say much of this alloy, but it is so hard that no tool can machine it, so ductile that it will stretch 25 per cent. or more in 8 inches. With a tensile strength of 140,000 pounds, its elastic limit is only about 60,000 pounds, and the modulus of elasticity is but about 85 per cent. of that of carbon steel. It can neither be softened nor hardened by heat treatment, so that its usefulness is confined to castings which are finished by grinding. This steel is almost unbreakable under the drop, and is astonishingly stiff under the blows. A water-toughened specimen is said by Hadfield to have stretched 50 per cent. in 8 inches, with a tensile strength of 145,000 pounds. Car wheels and other steel castings are being made in this country of manganese steel by the Taylor Iron and Steel Company.

The exact effect of silicon is disputed, but probably it has little, if any, hardening effect. Its presence undoubtedly results in a sounder ingot and consequently in a more highly finished product. Silicon has been said to cause red-shortness, but this is surely not the case. Steels of 0.50 per cent. silicon have been rolled into good rails, so that if this high-silicon steel could be rolled at all the ordinary high percentages cannot cause red-shortness. In recent years there has been a tendency toward the use of higher percentages of silicon. High-silicon steel has been recommended by European ordnance boards for gun-barrels, and silicon seems to improve the wearing qualities of rails.

Sulphur is notable chiefly for its well-known effect in making steel red-short. It has also a slight hardening effect.

The only consideration given to this element is the effort to keep it at a minimum. This is done by the selection of pure, low-sulphur ore, pig iron and coal. Iron will absorb sulphur from any source with which it may be brought in contact. It is desulphurized by the use of manganese, as noted above. Steel from eastern mills usually contains from 0.03 to 0.06 per cent. of sulphur.

That from western mills sometimes contains 0.10 and 0.12 per cent. English rails have been known to have even 0.2 per cent., but such stock could be rolled only at an intolerably high temperature. The allowable percentage of sulphur depends much on the amount of manganese present. Sulphur is so troublesome to the steelmaker himself, that he needs little urging from the user to induce him to keep it at a minimum.

Prior to the introduction of the basic process the presence of phosphorus rendered much ore unfit for steel making. It necessitates the greatest care in making steel by the acid process. Iron will not dephosphorize on an acid lining, so there must be a minimum of that element in the original ore and pig; but muck bar used in the Open Hearth process may first have the phosphorus reduced in a puddle furnace before coming to the steel bath.

Whatever effect phosphorus may have on steel under slowly applied loads, there is no doubt that it makes it extremely brittle under shock. The effect of phosphorus on steel varies with the percentage of carbon, being more harmful with steel of high carbons. Great care should be taken to specify a limit to the permissible phosphorus, for its presence does not prevent forging and rolling, even when unusually high, and it may have no great effect on the ordinary physical tensile test, and yet it may be fatal to the integrity of the steel under shock.

Nickel is an element only recently introduced into steel making. Its use has resulted in steels of the most remarkable properties and of the widest interest to steel users. Expense is the only bar against its universal use for all purposes. The writer has tested nickel steel bars ranging from 2 per cent. to 27 per cent. of nickel. The lower percentages raise the tensile strength, elastic limit, extension and contraction, and largely increase the ratio of elastic limit to tensile strength and of contraction to extension. It makes the grain finer and the steel tougher. Bars cut from a seventeen inch nickel steel, hollow forged, oil tempered shaft for the United States Navy gave results as follows: tensile strength from 90,000 to 94,000, elastic limit from 56,000 to 60,000, extension 26 to 28 per cent., contraction 59 to 61 per cent. With an elastic limit equal to that of gun steel, is combined an extension equal to that of the softest metal. It also gives to steel a quality that has necessitated the use of a new word, non-fissibility. A nicked bar of 27 per cent. nickel may be bent double without breaking beyond the nick. The life of the metal under alternating tension and compression is also greatly increased. The following is from private notes: Rolled bar nickel steel 5½ per cent. nickel, hardened and

annealed. Tensile strength 127,000, *elastic limit 117,000*, extension 21 per cent., contraction 61 per cent. This, I think, will interest every steel user. Also the following: nickel 27 per cent., tensile strength 100,000, elastic limit 47,000, *extension 47 per cent.*, contraction 61 per cent. This shows a pretty wide variation of qualities with the different percentages of nickel. The 27 per cent. nickel steel will not rust even in salt water, and may be bent, after nicking, without breaking, but 27 per cent. is beyond the point where nickel increases the tensile strength. As may be seen, the 27 per cent. steel is much lower than the $5\frac{1}{2}$ per cent. steel in this respect, although higher in extension.

Besides the foregoing elements, chromium, tungsten and aluminum are used in the manufacture of steel. Chromium, to make the well-known "chrome steel," used for armor-piercing projectiles and burglar-proof safe plates and jail bars. "Mushet's Special" is a tungsten steel well known in this country. Aluminum is used in Mitis steel castings. Copper steel has been tried and has shown some remarkable properties, but has never gone beyond the experimental stage. The tests showed a high elastic limit, but the steel was unsound.

SEGREGATION.

During the cooling of an ingot, some of the elements separate from the mass and consolidate toward the top of the ingot. Phosphorus shows the highest proportional segregation, and sulphur the next. Carbon segregates more than any other element, because it is present in such excess over the others. Silicon and manganese segregate very little. The segregation is in proportion to the time of cooling, and, therefore, generally proportional to the size of the ingot. The segregation of phosphorus and sulphur is often so great as to make their percentage, at the top of the ingot, dangerous where otherwise it would be harmless. Herein lies one of the dangers of making a forging from an ingot but little heavier than the finished work is to be. It is often advisable to discard 30 per cent. of the ingot in order to obtain the very best results. Cases are on record where the steel bath contained only 0.09 per cent. phosphorus and 0.08 per cent. sulphur, while the segregation had 0.28 per cent. phosphorus and 0.27 per cent. sulphur. This is a comparatively new field for investigation, but its importance cannot be over-estimated. In preparing specifications, great care should be taken to specify the minimum size of ingot and the amount to be discarded.

PHYSICAL DEFECTS.

As. steel solidifies, the gases it contains are forced out and take the path of least resistance. As the bubbles of gas approach the surface, they come into contact with solidified metal and are imprisoned there, forming blow-holes. These are naturally located chiefly near the surface of the ingot and are more numerous toward the top. When they are separated from the surface by only a thin skin, which may be oxidized through in heating, they do not weld up, but form various surface defects in rolling. Uneven heating and cooling sometimes results in cracks, which become seams when rolled. Steel, in cooling, first contracts until it reaches the melting point, when, like water, it expands, and, after becoming solid, again contracts. This action produces a cavity in steel ingots near the top and in the center. This is the "pipe," and, when it does not weld up, it is of course apparent in the finished work. This part of the ingot should be cut off before farther working. In steel castings this pipe is avoided by adding, above the casting proper, an additional mass of steel called the sinkhead. This is connected with the casting and is so proportioned that the pipe may come in it.

To avoid these physical irregularities in ingots, fluid compression is used in some mills. The Whitworth system is used at Bethlehem. The metal is poured into a flask of steel, around the edges of which are passages to allow the escape of the gases. This flask, after being filled, is placed under the ram of a hydraulic press, and pressure applied as high as 7000 tons on the top surface of the ingot. Under this pressure, the gases are driven to the sides and escape through the passages left for that purpose. The metal is forced down into what would be the pipe, and a perfectly solid ingot results. The segregated top is cut off, and, if a hollow forging is to be made, the inferior central metal is bored out, the result being an ingot as nearly perfect as possible.

THE EFFECT OF WORK.

Steel is hot-worked by rolling or by forging. Forging may now be again divided into hammer forging and press forging. All forms of hot working have certain effects in common. Work forces out the slag; compresses, closes up, and in some cases welds up the blow-holes and pipe, and refines the grain. These actions result in the improvement of all the physical qualities, tensile strength, elastic limit, extension and contraction. The *amount* of work alone influences the first two points, *i.e.*, reducing the slag and blow-holes, the temperature not being vital. But the refining of the grain is influenced, not only by the amount of work, but also

by the finishing temperature. It is almost axiomatic that steel finished at a high temperature will lose much of the refining effects of the work as it slowly cools and will be coarse grained in proportion to that temperature. The effect of work on the grain of steel is similar to that of heat treatment, it is also a function of the amount of kneading received. As a result of this it follows that in making large forgings it is important to use an ingot of such size that the reduction may be at least one-half. The effect of work is also inversely as the thickness of the metal, and the depth to which the good effect goes is proportional to the weight of the hammer or to the hydraulic pressure. Hollow forging under the hydraulic press gives better results, as it divides the thickness of metal by two, the mandril becoming an anvil and the reaction of the anvil itself being equal to the pressure of the ram. This is not true in hammer forging, especially if a light hammer be used, as the effect is produced only on the surface and there is a tendency to draw out the surface away from the central core. This action, together with too rapid reduction, sometimes produces actual internal rupture in the steel, which will not again weld up. Injudicious forging sometimes results, also, in a laminated structure, showing as parallel lines in a broken tensile specimen, and much reducing all the physical qualities of the metal. The hardening effect of work is also a function of the amount of carbon present. Its good effect may be entirely removed by heating to a sufficiently high temperature and slowly cooling. To illustrate this point the writer conducted a series of experiments on Open Hearth steel, varying from 0.08 per cent. to 1.20 per cent. carbon and through temperatures varying from 1000° to 1400° Fahr. These results would also be a guide to the proper finishing temperature. The following are some of the results:

Carbon.	Treatment.	Tensile Strength.	Elastic Limit.	Extension.	Contraction.	
.08 C	Unannealed	54,000	36,000	32%	65%	Carbon very low. No great effect on physical qualities.
	1400° F. Annealed	51,000	31,000	35%	70%	
1.20% C	Unannealed	145,000	84,000	3%	5%	Carbon very high. Note the great effect of temperature on all qualities.
	1000° F. Annealed	128,000	80,000	2.5%	5%	
	1400° F. Annealed	96000	46,000	19%	31%	

From such a table, backed by a sufficient number of experi-

ments, it would seem feasible to tell exactly at what temperature a steel of any carbon percentage should be finished in order that it should give the desired results.

Cold working in tension increases the elastic limit of tension and reduces the elastic limit of compression. Cold working in compression has the reverse effect. In either case it tends to reduce the extension and to make the steel brittle. These effects may be annulled by subsequent annealing. In the case of punching and shearing, the injured metal is usually removed by reaming and planing. In drawing wire and tubing, also in cold rolling and hammering, it is often desirable to retain this hardening, and consequent stiffening, effect.

HEAT TREATMENT.

The simplest heat treatment, and one to which all large forgings and castings should be submitted, is annealing. The primary object of this is to remove the bad effect of internal strains. In steel castings, which shrink twice as much as iron castings, it is absolutely necessary; for sometimes, when the pattern is complicated, the strains set up by cooling are great enough to rupture the metal. The necessity for annealing forgings increases with the carbon as illustrated in experiments noted above. Annealing removes some of the good effects of forging, while relieving the internal strains. There is therefore, in each case, a certain point which gives the best net results. Annealing always increases the percentage of extension and contraction, and generally lessens the tensile strength; but the elastic limit may be increased by annealing when the temperature is such that the good results of relieving the internal strains exceeds the reducing effect on the elastic limit due to softening. Below is one case from private notes. This example is notable also on account of the unusually high manganese and silicon present.

Manganese, 1.8% ; Carbon, 0.39% ; Silicon, 0.62%.

	Tensile strength.	Elastic limit.	Extension.	Contraction.
Unannealed	140,000	82,000	14%	23%
Annealed	118,200	88,900	22.50%	52%

HARDENING.

It has been proven that all steel is capable of being hardened. In steels low in carbon it is a question only of sufficiently high

temperature and a quenching medium of sufficiently low temperature and high specific heat. The mildest hardening effect can be obtained by plunging into melted lead. Gun, engine, and other large forgings, where no great hardness is desired and where too rapid cooling would be dangerous, are hardened in an oil bath. Cutting tools are hardened in water. Armor plate, the surface of which is very high in carbon, due to Harveying, and where the hardest possible surface is wanted, is quenched by a spray of iced water. Steel with the least possible carbon can be hardened by heating to a very high heat and quenching in mercury.

In the case of large steel forgings, for ordinary purposes, oil hardening seems to be the only practical method. Here the hollow forging again has the advantage, as it enables the cooling to take effect on both sides, giving deeper penetration and lessening the danger from internal strains. The effect of hardening is similar to that of forging, inasmuch as it breaks up the coarse crystalline structure and may even remove bad laminations. At the same time it hardens the steel and raises the tensile strength and the elastic limit, but reduces the extension and contraction so much as to necessitate a partial re-annealing. The following is an example of the effect of oil hardening on a forged bar of steel:

Carbon, 0.37% ; Manganese, 0 80%.

	Tensile Strength.	Extension.	Contraction.
Before Hardening................	90,900	20.0%	52%
After Hardening..................	132,400	4.5%	38%

Nickel greatly increases the hardening effect, as shown in the following case, where the carbon is ten points lower than in the above, but where the steel shows a phenomenal tensile strength after hardening:

Carbon, 0.27% ; Manganese, 0.70% ; Nickel, 3%.

	Tensile Strength.	Extension.	Contraction.
Before Hardening.........	98,000	18%	55%
After Hardening..................	227,000	1%	not perceptible.

These were plain bars of ⅞ inch diameter and hardened by the blacksmith.

As noted above, after the steel is hardened it is necessary to anneal or draw down the temper to the desired point. This point of course varies with the qualities wanted and with the percentages of the carbon and of nickel present. The following is an example:

0.66% Carbon

	Tensile strength.	Elastic limit.	Extension.	Contraction.
Annealed	127,700	66,000	12%	20.5%
Hardened and Annealed	153,300	92,000	13%	30%

This shows improvement in every quality by the double treatment.

0.46% Carbon Steel.

	Tensile strength.	Elastic limit.	Extension.	Contraction.
Annealed	98,000	48,000	21.6%	29.9%
Hardened and Annealed	104,000	61,000	22.5%	50.0%

0.14% Carbon Steel.

	Tensile strength.	Elastic limit.	Extension.	Contraction.
Annealed	72,000	41,000	31%	60%
Hardened and Annealed	74,000	44,000	31%	70%

This shows how the effect varies with the carbon. A steel may be still farther improved by being re-treated. Each hardening refines the grain, and after annealing the net effect is always a considerable gain.

Excellent qualities can be obtained in properly handled steel, but there are many reasons why steel should show bad qualities when not properly treated. It is the most valuable of materials for forgings, but the necessity of rigid specifications and of intrusting the work to those who are experienced and who have proper facilities for manufacture, must not be neglected. Most, and perhaps all, of the mysterious failures, the so-called treachery of steel, is traceable to bad composition, careless or ignorant cooling of the ingot, insufficient discard, too rapid reheating, forging under too light a hammer or too rapid reduction, insufficient work, a finishing temperature either too high or too low, and incorrect heat treatment after forging. None of these things are vital in handling wrought iron. Hence any manufacturer, accustomed to working iron only, is likely to make a poor job in the case of steel.

SURVEYING MINING CLAIMS.

By Charles Tappan, Associate Member Montana Society of Engineers.

[Read before the Society, May 8, 1897.*]

Surveys of mining claims by United States Deputy Mineral Surveyors, for the purpose of securing a patent from the United States, "must close within five-tenths of a foot in one thousand feet." (See Manual for 1895, page 10.) This requires an accuracy in the azimuth of the courses within two minutes of the true meridian. To get results within this small limit of error and to run from five thousand to eight thousand feet of lines per day over a rough mountain country is what a deputy is usually expected to do. The work is naturally divided into two heads, the Transit work and the Chaining.

THE TRANSIT WORK.

To "deflect a course from the true meridian" with an error of only two minutes, it is necessary to have a good instrument. Personal habits and tastes will cause one man to prefer an instrument that another might consider very undesirable. My own preference is for a very small and light transit, the instrument and tripod together weighing about twelve pounds and not encumbered with any solar apparatus, except a prismatic eye-piece to take direct observations on the sun. Not being familiar with the solar compass, I shall not attempt to discuss its merits, but will merely say that I have heard it reported by members of this Society as being capable of setting off a line with only one minute of error. Excellent results can be obtained by direct observations on the sun and reducing the observations by the formula

$$cos.\ \tfrac{1}{2} Az = \sqrt{\frac{cos.\ S.\ cos.\ (s - p)}{cos.\ \Phi\ cos.\ h}}$$

where Φ = latitude, h = sun's altitude, p = sun's polar distance, and s = half sum of the three. There are several other solutions of the triangle, but the foregoing is the shortest. When s is greater than 84 degrees this formula should not be used, because the cosine of large angles varies so rapidly. It is better, in such cases, to use the formula:

*Manuscript received July 3, 1897.—Secretary, Ass'n of Eng. Socs.

$$\sin. \tfrac{1}{2} Az = \sqrt{\frac{\sin.(s - \Phi)\sin.(s - h)}{\cos.\Phi \cos. h}}$$

Instead of depending on one sight at the sun and one reading of the circles, it is better to take either two or three sights at the sun with the telescope erect and then two or three with the telescope reversed (to do this it is necessary to have a full vertical circle); read the horizontal and vertical circles at each sighting and take the mean for the computation. This corrects errors arising from non-adjustment of instrument, especially errors in the collimation, from unequal height of standards and in the vertical circle. It takes only a few minutes longer to take the several sights and readings.

Always take a sight at the mark or foresight after observing the sun, to be certain that the transit has not moved during the observations. If the tripod has been wet, and if the observation is made the first thing in the morning, the heat of the sun may easily turn the transit two or three minutes. If possible, observations should be taken both before and after noon. The latitude usually offers the greatest difficulty in this method of getting the course. It is so often inconvenient to take a latitude observation at noon, that the great majority of these computations are made from latitudes calculated from the public surveys. As the error in latitude, for a morning observation, causes an error in the result with an opposite sign from that of an afternoon observation, the mean of the two, provided they are taken at equal hours from noon, should give the correct azimuth. By using Professor Johnson's "Table of Errors in Azimuth by Solar Compass" (reprinted in Gurley's "Ephemeris"), one can compare morning and evening observations taken at different hours from noon. For example, observations at latitude 40 degrees at 10 A.M. and 5 P.M. give a difference of four minutes in azimuth. By the table, the morning observation would be 2.6 minutes, the evening observation 1.3 minute out, and the latitude one minute out. By making a new set of computations with corrected latitude, one can ascertain whether the difference is actually occasioned by using the wrong latitude, or by some other error. If the former, the observations may be considered correct. If the latter, a new observation should be made.

In running lines, it is not usually necessary to use hubs with tacks. Almost always, in a mountainous country, unless the timber is heavy, a backsight or a foresight upon a distant object makes it easy to keep a line straight within an inch in fifteen hundred feet, without being over careful in centering at each hub. It

is very convenient, for future use, to sketch, in the field-book, the object used as a sight, and show the cross wires in the sketch.

CHAINING.

The long, thin steel tape is now almost universally used in this kind of surveying. The length of tapes depends greatly upon the character of the country, whether rolling hills, rough, rocky mountains, timbered or open. In the Upper Yellowstone country I first used a 300-foot tape, but the country was either so exceeding rough, or else so heavily timbered, that about as rapid progress could be made with a 200-foot tape. In Utah, especially in the foothills, distances of five hundred feet and more can very frequently be covered with one stretch of the tape. Experiments on a carefully measured base 492.4 feet long, across a gulch, showed that a 500-foot tape could be stretched by two men of ordinary strength, using a pull of probably seventy pounds, to within less than one-tenth of a foot of the actual distance. The pull was not measured by a spring-balance. It was as heavy a pull as could be conveniently made by a one hundred and fifty pound man, with the tape held as high as the telescope of the transit. In these experiments the tape was suspended clear of all supports, the angle of elevation, from one station to the other, was 5 degrees, the length of tape between stations 494.3 feet, which, multiplied by cosine 5 degrees, is = 494.42 feet. The tape was an ordinary Roe & Sons tape, marked every five feet with brass or copper plates, and every foot with a rivet. It is best to measure from the end of the telescope axis, and to measure the vertical angle to the hand of the head chainman. The precision with which the vertical angle should be measured depends upon the steepness of the slope. For slopes less than 20 degrees, it is sufficient to read to fifteen minutes. For reducing the measured distance to the horizontal, the most convenient thing to use is an old-fashioned traverse table, such as is found in Scribner's "Pocket Book," or Roe's "Pocket Book." These have distances to one hundred for each $\frac{1}{4}$ degree. As the tables are to two places of decimals, they can be used for distances up to one thousand feet for one decimal.

The error that most frequently enters into this method of chaining is that of reading the tape length ten feet wrong; *e.g.*, one has the 178-feet rivet, the first thing noticed is that the unit is 8, and as the 180-feet plate is the one seen first, the distance may very easily be written 188 in the note-book. By having the back flagman hold the back end of the tape upon the last station, one can double chain every line at the expense of very little extra time, except

where the country is so open that the head chainman can proceed before the deputy reaches the next station. It is a very good practice to check by stadia. As stadia rods are always cumbersome, it is desirable to find some good substitute. A piece of stout canvas about one inch wide, six feet long, and painted like a Philadelphia leveling rod, with a plumb and bob fastened to one end, can be easily read up to distances of five hundred feet, and when held by the top is sure to be plumb. This pocket rod is also very convenient in setting hubs that are hidden by intervening rocks or low brush, and for measuring distances to corners of buildings and other improvements, where extreme accuracy is not essential.

A very pretty check on the chaining of long lines can be made whenever some distinct object is visible from both ends of the line and from one or more points along the line. Say the line is fifteen hundred feet long, and at the start a dead tree-top is seen 30 degrees to the left. By measuring the angle to the tree-top at five hundred, one thousand and fifteen hundred feet, one has the base and two angles of three adjacent triangles. If the line common to two triangles is the same length when computed from either triangle, it follows that the line measured is correct. It takes but a few seconds to measure the angles, and a few minutes to make the computations. If the object is properly situated, it can be used as a check on the end lines.

DISCUSSION.

Mr. John Herron.—Mr. Tappan's paper is an expression of that improvement which the practice of to-day shows over the work of past years. It surely speaks well for the profession when we see these attempts to make surveying something more than a mere trade. It has long been customary to consider accuracy nonessential in the survey of the surface lines of a mining claim, and there are but few of us who have criticised the work of our fellows as lacking in this respect. The calculation of field notes may show that a survey has closed within the prescribed limits of errors, and yet the actual positions of corners and lengths of boundary lines may vary greatly from the result of the calculations.

There is no gainsaying that the official survey of a mining claim should be exact—not an approximation. It is useless to lay down rules which give results that are "close enough." Those of us whose work has led into the projection of the boundary lines of claims to the lower levels of deep mines, know what a few feet may mean in the proximity of an ore body.

No surveyor nowadays trusts his chainman to hold a tape line horizontal on a steep mountain side. It cannot be done except in such short lengths that the frequent "breakings of chain" is in itself a source of error. The method of chain measurements outlined by Mr. Tappan is the one productive of best results, where reasonable speed is desired. If carefully done, it will vary but little, in the length of an ordinary claim, from the result obtained by measuring the slope distance between points as an hypotenuse, obtaining the perpendicular by a line of levels, and calculating the base for the horizontal distance. This is tedious, if the line be long, as the result required is the sum of the bases of a number of triangles—depending on the length of the chain or tape used. I differ from Mr. Tappan as to the utility of transit points. For good work I believe in placing hubs with tacks at every chain-length, using every other one as a transit point. Then, with an assumed datum as the elevation of the starting point, noting the height of instrument, the vertical angle is read to the first station ahead and the slope distance from axis of instrument is measured. Then, moving to the second station, the vertical angle and the slope distance are taken, back to the first station, and ahead to the third station, after which the transit moves to station No. 4. The advantage of this method is that, simultaneously with the transit line, a line of levels is being carried on which may be of great use—some day—to some one, if not to the man who makes the survey. It also offers a method of checking work, as satisfactory as the stadia, for a vertical angle can be read to any point on the line whose elevation has already been determined, which elevation should be the present height of instrument, plus or minus tangent of vertical angle multiplied by horizontal distance, as shown by notes.

The writer has in mind an example of extreme accuracy in a survey made in this manner. In the trial of an important mining suit the respective parties exhibited maps of the claims in controversy, including the underground workings. One map had been prepared from very careful triangulation surveys, extending over a period of several years, and from carefully run lines of levels. The other map was prepared from notes of surveys made in the manner referred to. Both maps showed surface and underground workings extending over a distance of about half a mile in plan, and comprising several miles of actual surveys, yet tracings of both maps corresponds almost exactly, and levels between points nearly six hundred feet apart vertically, which required three-quarters of a mile of surface and three-quarters of a mile of underground surveys, checked within 0.52 feet.

Meteorological Investigations in the Free Air, at the Blue Hill Observatory, Milton, Massachusetts.

By A. Lawrence Rotch, S.B., A.M., Director.

[Read before the Boston Society of Civil Engineers, May 19, 1897.*]

In their relation to the atmosphere, men resemble organisms which inhabit the depths of the ocean: and the slowness of the development of meteorology into a science is due to the difficulties of exploring the aërial ocean. The earliest attempts to explore the upper air were, of course, made by mountain and balloon ascensions, and it is worthy of remark that the first scientific balloon voyage was made by a Bostonian, Dr. John Jeffries, in 1784, from London. During the next century there were many high balloon ascents. In 1862, Glaisher, in England, rose nearly six miles, and, in 1893, Berson, in Germany, reached about the same height, and, with improved instruments, obtained, for the first time, trustworthy data. Balloon ascents, however, are sporadic and give little information about the atmospheric changes which occur from day to day. Continuous observations can be made only on mountains, and in this respect great strides upward have been taken during the past twenty years. The French have expended the most money on their outposts, which are fortresses to withstand the fury of the elements, but the most valuable results have been derived from the Austrian stations under the direction of Dr. Hann. The highest meteorological station in the world, which, instead of observers, has an automatic recording apparatus made by Mr. Fergusson at Blue Hill, is maintained by the Harvard Observatory on El Misti, in Peru, at an elevation of over 19,000 feet.

The Blue Hill Observatory is not a mountain station, but the conditions there are approximately those of the free air just above the surface of the earth. As an illustration of the effect of the friction of the ground on the wind, it may be stated that its velocity on Blue Hill averages 60 per cent. greater than on the tower of the Post Office in Boston, only 460 feet lower. The influence of the artificial heating of a city, in raising the air temperature, is shown by the fact that the difference between the Boston and Blue Hill temperatures in winter is greater than the mean difference for the year, which is about three degrees.

I now come to the special subject of my paper, the investigation of the free air from the summit of Blue Hill. Soon after the

* Manuscript received July 22, 1897.—Secretary Ass'n of Eng. Socs.

foundation of my Observatory, in 1885, detailed cloud observations were begun by Mr. Clayton, and nowhere else in the United States has so much attention been given to the study of clouds. There is a long record of the amount of cloud at each hour, consisting of personal estimates during the day and of an automatic record at night by an instrument called the Pole Star Recorder, which gives a continuous photograph of the sky around Polaris. When the trail of the star on the photographic plate is unbroken the sky around Polaris is clear, while when the trail is broken or

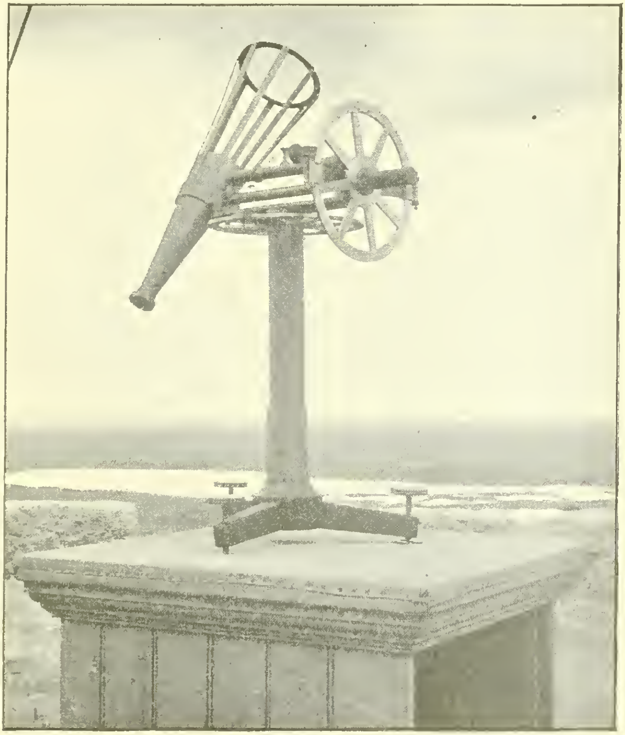


FIG. 1.

obscured the sky is partly or entirely covered with clouds. The direction of motion and relative velocity of the clouds are frequently observed by means of a cloud mirror or nephoscope. The measurement of cloud heights was begun in 1890 by Messrs. Clayton and Fergusson according to the system previously used at Upsala in Sweden. These theodolite measurements were again undertaken last year here, and also in Washington in connection with an international scheme of observation. The method is as follows:

At two stations, a mile or more apart, two observers each with the specially constructed theodolite shown in Fig. 1, measure the azimuth and altitude of some point of a cloud whose identity is assured by telephonic conversation. Synchronous observations are secured by the beating of an electric pendulum. The probable error of the calculated heights of the highest clouds is only a few hundred feet. Simultaneous observations of the position of the cloud, at a definite interval of time, enable its velocity to be calculated, or this may be obtained from the relative velocity when the height is known. Four other methods of measuring cloud heights are employed at Blue Hill. One of them is by the shadows of low clouds. The angle of the cloud from the Observatory is measured, the angle of the sun with the horizon is found from tables, and the distance of the shadow on the landscape is ascertained from a map. These elements of a triangle enable the cloud height to be calculated, and its velocity may be determined from the time of passage of its shadows over known points. The only method of measuring certain high and uniform cloud strata is by means of the light reflected upon them at night from cities. The angle which the center of the illumination makes with the horizon is measured; and, having the distance of the city, the right-angled triangle may be solved. An accurate method for low and uniform clouds is to send up kites into and through the clouds. The amount of line and its angle when the kites disappear give the height of the lower surface, and the records of barograph and hygrograph, which are carried by the kites, determine the upper limit of the cloud, and, therefore, its thickness. Still another method, for very low stratus or nimbus, is to note the height of the base on the sides of Blue Hill.

As a result of these measures, the heights and velocities of drift of the various clouds are accurately determined. The mean height of the cirrus cloud is about 29,000 feet, though it is sometimes found as high as 49,000 feet. The mean height of the cumulus is 4600 feet, or a little less than a mile, but the tops of the cumulo-nimbus, or thunder-shower clouds, penetrate into the cirrus region. The average height of the nimbus, or rain-cloud, is only 2300 feet, and it often sinks below the top of Blue Hill. The average velocity of the cirrus clouds is 89 miles an hour, but in winter they sometimes have the enormous velocity of 230 miles an hour. The observations show that the entire atmosphere, from the lowest to the highest level, moves twice as fast in winter as in summer, and that between heights of two and nine miles there is an almost continuous westerly current of great velocity, the in-

crease of velocity from the lowest to the highest clouds being a linear function of the height. Whenever clouds are visible, therefore, it is possible to ascertain the direction and velocity of the currents at the levels at which they float. Those readers who are interested in the subject of clouds will find a discussion of the Blue Hill and related data, by Mr. Clayton, in Part v, of vol. xxx, of the *Annals of Harvard College Observatory*, which a competent writer in *The Nation* has termed "by far the most thorough study of the kind ever undertaken in this country, if not in the world."

More important factors in the science of the weather, because they are causes rather than effects, are the changes of barometric pressure, air temperature and humidity with height. The former can be determined only by observations at fixed heights, as on mountains, but the other elements are greatly affected by the mass and covering of the mountain upon which the observations are made. I have already stated that daily observations in free balloons are impossible, while their rapid passage through the air makes observation at fixed points difficult. Moreover, the balloon itself, heated by the sun, affects the temperature readings unless special means are taken to avoid this, and so all the early balloon observations are probably more or less inaccurate. Captive balloons have been tried for exploring the lower air, both with observers and with self-recording instruments without observers. Their height is necessarily limited by the weight of cable, and strong winds drive them down, so that heights exceeding 2000 feet can hardly be attained. Their cost, also, is a drawback. Kites have none of their disadvantages and they fail only when there is too little wind at the ground, a condition which seldom extends aloft.

The honor of making the first thorough exploration of the lower mile of free air belongs to the Blue Hill Observatory, and especially to Messrs. Clayton, Fergusson and Sweetland, my assistants, who have devised new apparatus and methods, and have carried the work to such success that it is being imitated in this country and in Europe.

Although the first scientific use of kites is commonly attributed to Franklin, it is now known that three years previously, that is, in 1749, Dr. Wilson, in Scotland, sent into the clouds thermometers attached to kites, and in 1822 the temperature in the Arctic regions was obtained by self-registering thermometers raised in this way. The first systematic use of kites in meteorology was in 1883, when Archibald, in England, obtained differential measures of wind velocity by anemometers attached to kites flown tandem with steel wire. These instruments indicated only

extremes or totals, and it was necessary to record graphically and continuously before simultaneous observations could be obtained at the ground and in the free air, and upon doing this depends the value of our work at Blue Hill. Up to this time self-recording instruments were too heavy to be lifted by kites, but Mr. Fergusson remodeled a Richard thermograph so that it weighed only 24 ounces and, on August 4, 1894, this instrument was elevated about 1500 feet above Blue Hill. Since then, meteorographs recording three elements and weighing less than three pounds have been constructed by Mr. Fergusson, and by M. Richard for use at Blue Hill. They record atmospheric pressure, air temperature, and either relative humidity or wind velocity.

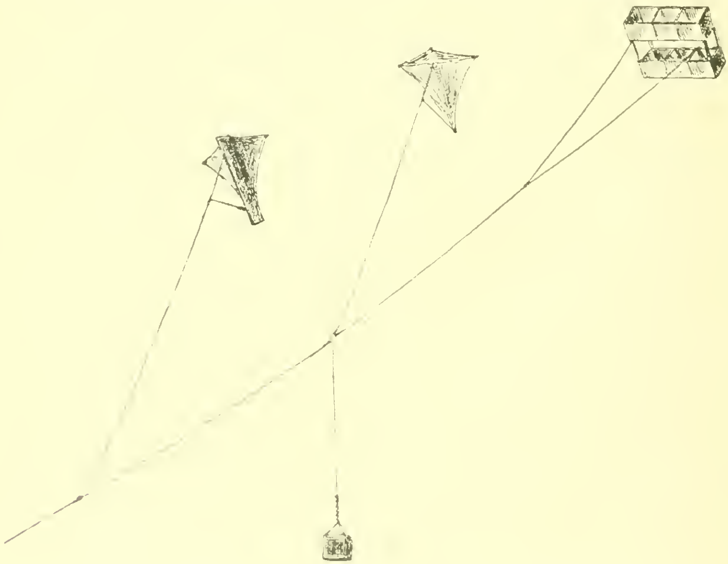


FIG. 2

A factor in the success attained was the substitution of steel music-wire for cord as a kite-line. The wire has the same weight as the cord, and is twice as strong and only one-sixth the diameter. This reduction of surface exposed, is important in lessening the wind pressure. The wire now used is No. 14, M. W. G., having a diameter of 0.033 inch and a tensile strength of about 300 pounds. Thus the analogy of these aërial soundings to the deep-sea soundings is borne out, and it will be completed by the substitution of a strain pulley and a storage reel, similar to that used in deep-sea sounding, for the present drum, which threatens to collapse under the accumulated pressure of the coils of wire. Several forms of kites are employed, such as the Eddy or Malay tailless kite, the

Hargrave or cellular kite, and, latterly, a kite with a keel on the front surface, devised by Mr. Clayton. These are shown lifting the metrograph in Fig. 2, while Fig. 3 gives a general view of the Observatory with the kites and the hand-reel. The kites weigh from two to three ounces per square foot of lifting surface which, in a twenty-five-mile wind, exerts a pull of about one pound on the line. The meteorograph is hung between two kites and other kites are attached to the wire at intervals so that its angle above the horizon shall not fall below 30° or 40°, notwithstanding the increasing weight of wire (15 lbs. per mile) and the pressure of the wind upon it. The pull on the windlass is recorded by a dynamo-

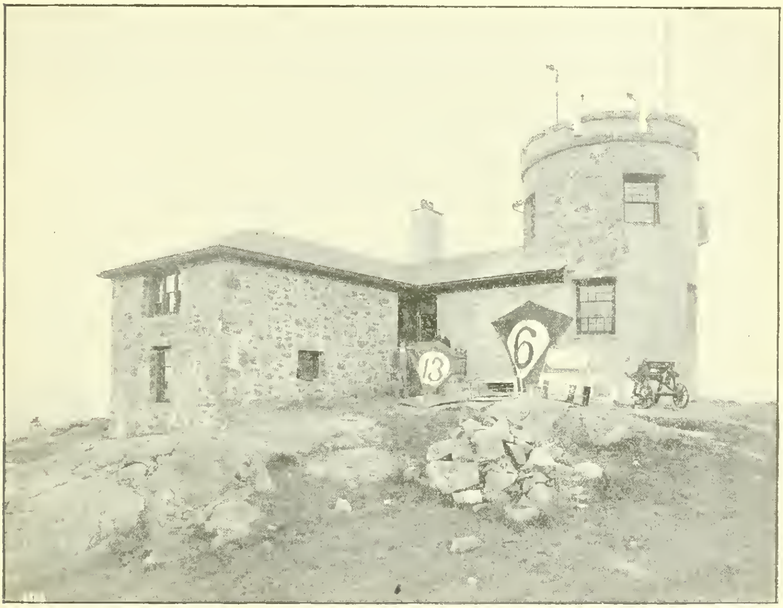


FIG. 3.

graph. A measuring device registers the length of wire uncoiled, and from this and from the angular elevation of the meteorograph, its vertical height is computed, after making allowance for the sag of the wire, which amounts to about two per cent. of its length. When the meteorograph is hidden by clouds, differential measures of its heights are obtained from its barometric record.

To sum up briefly the results, I may say that about 130 records have been obtained at all seasons and in all kinds of weather, with winds varying from fourteen to forty miles per hour. Several records have been brought down from more than a mile above the hill, and last October the maximum altitude of 8740 feet above the

hill, or 9370 feet above the sea, was reached. From the direction of the kites in different air strata, the change of direction of the wind at various levels is determined. Usually there is an increase of wind with altitude, the rate of increase being about 25 per cent. in the first 1000 feet. The changes of temperature and of relative humidity are often very abrupt. Thus, before a cold wave is felt at the earth's surface, the normal decrease of temperature with elevation (about 1° per 250 feet) is much accelerated, and before a warm wave comes on below, a marked inversion of temperature at a height of half a mile has several times been noted. The observations, so far as studied, seem to show that, at a height of a mile,

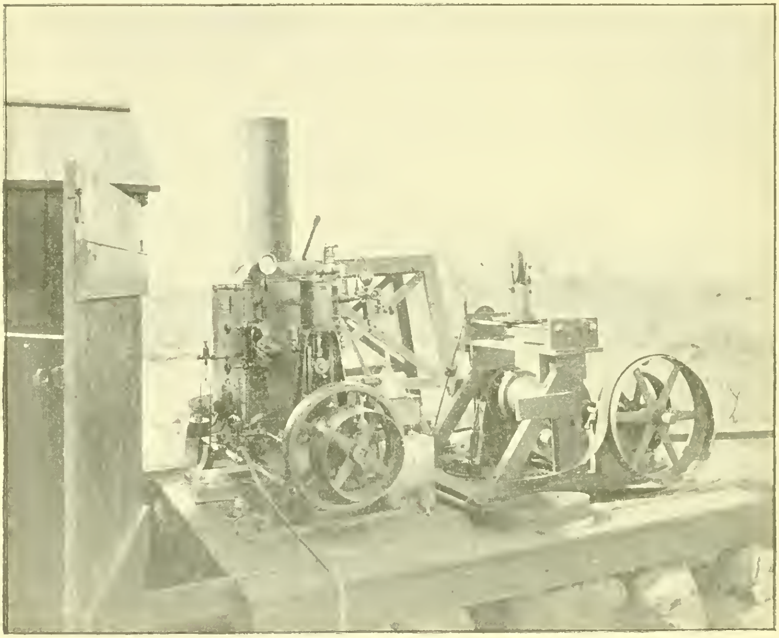


Fig. 4.

there is no diurnal change of temperature, but that in fair weather the days are damp and the nights are dry, or the reverse of what occurs at the earth's surface. A discussion of the observations will be published in the Annals with the Blue Hill observations for 1896. By means of a grant from the Hodgkins Fund of the Smithsonian Institution, a steam reeling apparatus was constructed last winter, and Fig. 4 shows the first application of steam to kite-flying. With perfected apparatus during the coming summer, it is confidently expected that records will be obtained at an altitude exceeding 10,000 feet above Blue Hill.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881

VOL. XIX. AUGUST, 1897. NO. 2.

OPERATION OF THE LOS ANGELES OUTFALL SEWER AND SEWAGE IRRIGATION.

BY BURR BASSELL, MEMBER TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, May 7, 1897.*]

A DESCRIPTION of the sewerage system of the city of Los Angeles was published in *Engineering News* of February 28, 1895. This included an account of the construction of the Outfall Sewer, which had been completed in the spring of the previous year. After a lapse of two years, the writer of the article feels warranted in giving an account of its operation.

The experience derived from the working of this plan, for sufficient time to test its merits will furnish valuable lessons for engineers and irrigators.

An apology is due the Society for presenting the subject matter of this paper in its present form; but owing to circumstances over which the writer had no control, he is compelled to do so, or else fail to present the paper as announced. His aim, therefore, has been to induce discussion and make the paper suggestive rather than exhaustive.

Map and profile of the Outfall Sewer, together with details of the most important structures, are shown on plates 1, 2 and 3.

The accompanying photographs may also serve to make the subject matter a little clearer.

Fig. 1. View of wood-stave pipe construction on Section 3.
Fig. 2. Blow-off on first siphon.
Fig. 3. Irrigating hydrant.

*Manuscript received July 10, 1897.—Secretary, Ass'n of Eng. Socs.

Section.	Name of Contractor.	Contract Price.	Construction. Begun.	Construction. Finished.	Length Feet.	Size and Character of Section.	Barrels of Cement Used	Remarks.
1	J. Rebman.	$12,018	Jan. 25, '93.	April 1, '93.	2,463	52 in. circular, two rings brick.	1,174	This section built large enough to carry the sewage of a city of 135,000 population.
2	Frick Bros.	24,085	Jan 5, '93	March 17, '93.	4,435	40 in. circular, two rings brick.	1,734	Only one line built at present
3	Mansfield & Grant.	39,000	Sept. 6, '93	Feb. 8, '94.	16,936	38 in. wooden stave pipe.	49	Secs. 3 and 6A required about 700,000 ft. B. M. Cal. redwood.
4A	Mackay & Young.	31,033	May 25, '93	Dec. 6, '93.	4,677	40 in. brick conduit, and 6 ft. oval tunnel.		1,883 lin. ft. brick conduit; 2,794 lin. ft. brick and concrete tunnel.
5A	Mackay & Young.	30,091	Aug. 11, '93	Nov. 10, '93.	3,842	6 ft. oval tunnel, 40 in. circular brick.	5,012	2,995 lin. ft. brick and concrete tunnel; 847 lin. ft. brick conduit.
6A	Mansfield & Grant.	38,450	Aug. 10, '93.	Jan. 10, '94.	17,174	36 in. wooden stave pipe.	72	All concrete specified, 1 cement, 2 sand, 6 gravel.
7	Frick Bros.	27,454	April 10, '93.	June 15, '93.	6,052	40 in. circular brick conduit.	2,292	All mortar for brickwork, 1 cement, 2 sand.
8	Hughes & Mayer.	24,602	June 15, '93.	Sept. 16, '93.	4,778	40 in. circular brick conduit.	1,583	
9	Frick Bros.	29,223	June 10, '93.	Oct. 11, '93	4,060	40 in. circular brick, and 6 ft. oval brick and concrete tunnel.	1,490	1,976 lin. ft. of brick conduit; 2,084 lin. ft of brick and concrete tunnel.
10	Hughes & Mayer.	10,735	Sept. 25, '93.	Nov. 30, '93.	1,200	24 in. cast iron pipe.	3	Flanged pipe with pure rubber band between each joint.
	Totals	$266,691			65,628	12.4 miles	13,400	

Figs. 4, 5 and 6. Views of launching cast-iron pipe.

Figs. 7 and 8. Break in Lateral No. 1.

For convenient reference the writer submits a table, as published in *Engineering News*, giving, for each section, the name of the contractor, date of construction, size and length of section, character of materials, quantities, cost, etc.

Those who may not have access to the files of that journal may be interested in a brief description of the Outfall Sewer, and some account of its construction.

The Outfall properly begins within the city limits at the intersection of Grand Avenue with Jefferson Street, and extends in a southwesterly direction to the Pacific Ocean, a total distance of 12.4 miles.

The line was divided into ten working sections of unequal lengths, and separate bids were received for each section, complete.

Section 1 is a circular brick conduit, 52 inches in diameter, 2463 feet in length, having a grade of 1 in 600. From the end of Section 1, the Outfall will eventually be a double conduit, excepting the tunnel portions, which were made large enough to carry the sewage of both conduits when built. Provision was made also at all structures for the second conduit.

Section 2 is a circular brick conduit 40 inches in diameter, 4435 feet in length, having a grade of 1 in 800. This gradient is maintained by means of vertical drops for all the remaining portion, excepting the siphons and the ocean section.

A settling chamber, designed to collect sand and other heavy substances, was built at the end of Section 2. It has four compartments, consisting of a receiving and discharge chamber at the ends, with two elongated apartments between, separated from the end chambers by a double set of boiler-plate sluice gates. The middle apartments are provided with sand-pits 4 feet deep, with horizontal screens over them, on the grade line of the sewer.

Section 3 embraces the first wood-stave siphon, which is 38 inches in diameter and 16,936 feet in length. On this section there are three blow-offs and five hydrants, with several additional manholes. The lowest portion of this siphon is about 27 feet below the hydraulic grade line. At the lower end was placed a butterfly valve provided with a geared handwheel, for easy manipulation.

Sections 4 and 5 are each partly in tunnel and partly in 40-inch brick conduit. The lengths of the tunnel and of the brick conduit are 5789 feet and 2730 feet respectively, aggregating 8519 feet for the two sections.

The tunnels are lined throughout, having a semi-circular

invert of concrete, and an egg-shaped arch of brick-work. In section they are $4\frac{1}{2}$ feet wide and 6 feet high. The average cross-sectional area of the excavation was about 52 square feet. The material encountered was mainly sand, and in places very fine and difficult to handle.

At the end of Section 5 is a drop-chamber, provided with gates for delivering sewage to Lateral No. 1.

Section 6 embraces the second wood-stave siphon, which is 36 inches in diameter and 17,174 feet in length. On this section there are seven hydrants, beside several manholes. The structures provided for delivering sewage to Laterals No. 2 and 3 will serve the purpose of blow-offs when necessary.

The lowest portion of this siphon is about 25 feet below the hydraulic grade line. It may be well to state, in this connection, that one straightway valve has been placed in each siphon since the sewer was finished, as will be noted later on.

The end of this siphon is provided with a butterfly valve, similar to the one at the end of the first siphon.

Sections 7 and 8 are 40-inch brick conduits, and aggregate 10,830 feet in length.

Section 9 has 1976 feet of brick conduit and 2084 feet of tunnel passing through the sand dunes skirting the coast.

The Ocean Section (No. 10) consists of 1200 feet of 24-inch cast-iron flanged pipe, extending originally 600 feet into the sea.

The pipe was bolted together with a ring of pure rubber, $\frac{3}{4}$ inch square, in each joint. This gave sufficient flexibility to the line to permit launching in the following manner:

On the sloping shore-front about 600 feet of pipe was first bolted together and placed upon two timber stringers, one on each side, to which the pipe was fastened by $\frac{3}{4}$-inch rods. Wooden rollers were placed between these stringers, and two lines of boards, 2 inches by 12 inches, were laid upon the ground. This whole line was then slowly moved out to its final position by means of capstans, operated by horse power. Figs. numbered 4, 5 and 6 show quite clearly the manner of launching. No attempt was made to anchor the pipe, or to protect in any way the portion lying on the ocean bed, the outer end being submerged in about 20 feet of water.

Littoral currents, resulting from heavy storms, have shifted the pipe about fifteen (15) feet out of alignment, causing it to break on shore at a point about one hundred feet from line of low tide. As soon as this occurred, the sewage, rushing out of the pipe at great velocity, cut out a large basin which kept constantly

encroaching upon the bluff. Section after section of the pipe broke off and dropped into the pool below. To stop this action, a short line of sheet piling was driven, at right angles to the sewer, near the base of the bluff, and a wooden flume was constructed to carry the sewage out some distance beyond. This is, of course, only a temporary solution of the difficulty. The sewage eddies around in a large circular pool, and has cut a channel northerly along the base of the bluff for about four hundred feet. It there flows into the ocean.

Upon examination of the exposed portion of the pipe, lying only partially imbedded in the beach sand, the writer observed that many of the bolts of the flanged joints were missing; that the rubber between the flanges seemed to have hardened, and that the $\frac{3}{4}$-inch rods, used at the time of launching to hold the pipe to the wooden stringers under which the rollers were placed, were entirely rusted and worn apart.

It is hoped that some of the following points of constructive details and experiences may call forth discussion from members of the Society:

The most important change or addition to the settling-chamber, which has been made as a result of practical experience, consists of an emergency wasteway conduit, 24 inches by 30 inches, connecting with the first apartment of the chamber. The conduit is provided with an ordinary sluice-gate with emergency overflow opening at the top.

This branch enables the superintendent to use the sewage on about four hundred acres of land which could not otherwise be irrigated, being higher than the first hydrant.

An additional grating, made of 1-inch iron rods placed vertically in front of the 38-inch siphon, and spaced 6 inches apart, center to center, was deemed necessary by the superintendent, after finding that some malicious person had dropped an empty barrel into the chamber below the rubbish screen first constructed.

The superintendent visits the chamber daily, and with a long-handled fork, having suitably curved prongs, forks the accumulated rubbish off the screens, and deposits it in closed boxes placed flush with the surface of the ground at each end of the chamber. These are carted away weekly at a cost of 50 cents per week.

A large quantity of fine sand accumulates in the pit and at the corners of the chamber. This is cleaned out about twice a year, but much the larger portion passes on through the sewer. In the article to which frequent reference is here made, the writer expressed his opinion that this chamber would prove useless except as a rubbish collector.

Regarding its use as a sand-box and arrester of "valuable articles," as advocated by the City Engineer, he is of the same opinion still. It has been made to serve a useful purpose, however, as an emergency wasteway and point of diversion for sewage irrigation.

The horizontal screens proved a nuisance when the chamber was being cleaned, and were abandoned as useless.

The specifications called for "hard-burned brick, with a crushing strength of not less than 2500 pounds per square inch." The brick and concrete work were both exceptionally good, largely due to the fact that the city furnished all the cement used, and also to the painstaking care of Mr. H. P. Vincent, the engineer who designed and superintended the construction of the sewer, who insisted upon the specifications being fully complied with.

The bricks were of a superior quality, and were thoroughly wetted by immersion before using. This is one of those small details the observance of which will cover a multitude of sins committed by masons.

The specifications for wooden pipes called for round rods of $\frac{5}{8}$ inch diameter, medium steel, with nuts not less than $\frac{7}{8}$ inch in thickness. The threads were to be of Franklin Institute Standard as to form, but to have sixteen threads per inch.

In the article referred to, it was stated that trouble was experienced during construction by the stripping off of the nuts while cinching the pipe, and that, upon finding they were not always uniformly and properly cut; this was thought to be the cause of the trouble. Others claim that there should not have been as many as sixteen threads per inch.

The cast-iron shoe used is locally known as the "Register Patent," and is faulty in at least one feature, viz: that the bands cross each other in such a manner as to produce a shearing strain on the projecting points. The first shoe used was cast so light that a large percentage of these points would break; the shoes were then made heavier, weighing three pounds each, and better results were obtained.

Considerable trouble was experienced also in making the siphons water-tight, owing to the fact that the wood-stave pipe was laid by inexperienced workmen and not properly cinched. The importance of seating the bands well into the staves by means of wooden mallets during the process of cinching was clearly demonstrated.

At structure 43A, the siphon deflects to the right $56\frac{1}{2}$ degrees, and, on account of the narrow right-of-way secured (15 feet), a boiler-plate knee was used in preference to a curve.

During the rush of construction, the City Engineer asked the writer to design a drop-chamber for structure No. 67, at the end of Section 8. He did so, making the length twelve feet. This design was criticised by some of his superiors as being unnecessarily large. The writer maintains that the *mean* velocity of approach should not be made the governing factor in determining the path of the jet, and that the graphical method, usually employed in such cases, showing parabolic curves, is incorrect. He hardly expects this statement, however, to lead to a Fanning-Frizell discussion.

Having observed the flow at this drop when the sewer was carrying only 10 second-feet, or less than one-third its full capacity, and that the overfall strikes the toe of the opposite wall even with a vertical drop of 10.61 feet (not including the water cushion), he is confirmed in his statement and thinks the mathematicians should revise their figures.

The necessity for blow-offs in the line of the first siphon is called in question by several engineers, and their practical utility remains to be demonstrated. The form of hydrant, shown in Fig. 2, would indeed be a pronounced success if one wished to take a sewage bath. Not being in demand for this purpose, they have all been incased in a wooden box, with an outlet on one side leading to the irrigating ditch.

Figs. 7 and 8 show a break in Lateral No. 1, which was built by private parties, and which is used to convey sewage to the lands of Messrs. Howard and Bixby. No comment is necessary upon the failure of the structure, the photographs clearly showing faulty design and workmanship. The bottom, sides and top were never properly united. It has been repaired by bolting together the ends of light iron rails, bent to the form of the conduit, and spacing them about four feet apart to hold the concrete together.

In order to permit the use of sewage from the upper portion of the siphon sections, and to avoid subjecting them to the pressure resulting from closing the valves at their extreme lower ends, two straightway valves, of the Ludlow pattern, were placed immediately below structures Nos. 19½ and 44A. A further reason for these gates was found in the excessive leakage of the butterfly valves, it being impossible to shut off all the flow in this way. The first butterfly valve has been entirely removed, owing to the accidental twisting off of the valve-stem.

No sewage has ever been used for irrigation from the lower portion of either siphon. Probably the most important question of constructive detail relates to the proper form of gates for an outfall sewer similar to the one we have under consideration.

Some engineers will doubtless claim that the butterfly valves were faulty in design, others that the principle of the butterfly valve is faulty. Those who defend the butterfly construction maintain that the sewer should never be permitted to become dry, because of accumulations that adhere to the invert.

The straightway valves were put in place about April or May, 1895, and they have given entire satisfaction through two seasons. Mr. H. P. Vincent, superintendent of construction of the Outfall, claims that he only followed instructions in designing such gates as were called for by the plans approved by the consulting engineer, the late Mr. P. J. Flynn. Mr. Vincent has always had grave doubts, however, as to the successful working of straightway valves in a sewer. These valves are massive and heavy, provided with slow-motion gear, requiring about twenty minutes to open or close. They have been placed in brick substructures with a wooden superstructure. In connection with each valve an air vent or iron stand-pipe, six inches in diameter and forty-two feet in height, has been placed a few feet below the valve.

The necessity for these vents has been called in question by at least one well-known engineer, who claims that the only pressure to which the lower portion of the siphons would be subjected, upon closing the gates, is measured by the difference in elevation between the lower ends of the siphons and the gates. This difference in elevation does not exceed five to seven feet. The writer must confess that he failed to comprehend the argument. It was even denied that a partial vacuum was formed below the valves, or that there would be any tendency in the pipes to collapse. Surely these are elementary principles of physics and hydraulics, but since they have been called in question by those entrusted with important hydraulic work, no excuse need be made for bringing them forward for discussion.

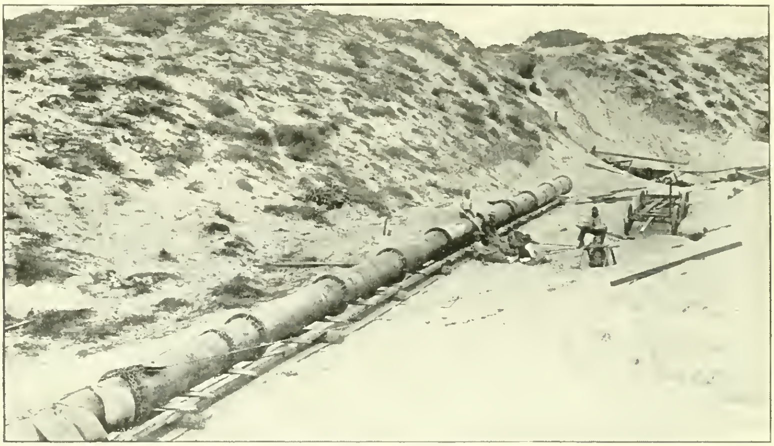
Upon witnessing their action, it seemed that some provision for an air vent was necessary. After the gates are three-quarters closed the air rushes into the siphon with great velocity, to fill the partial vacuum made by the outgoing sewage, causing the standpipes to vibrate to some extent and to sing like an Eolian harp. When the gates are finally closed, and for a short time before and after, the reaction within the pipes is so great that sewage is thrown out of the top of the stand-pipe for a distance of ten feet, or more than fifty feet above the sewer. The writer, on one occasion, saw a large ink bottle and other foreign matter thrown out in this manner.

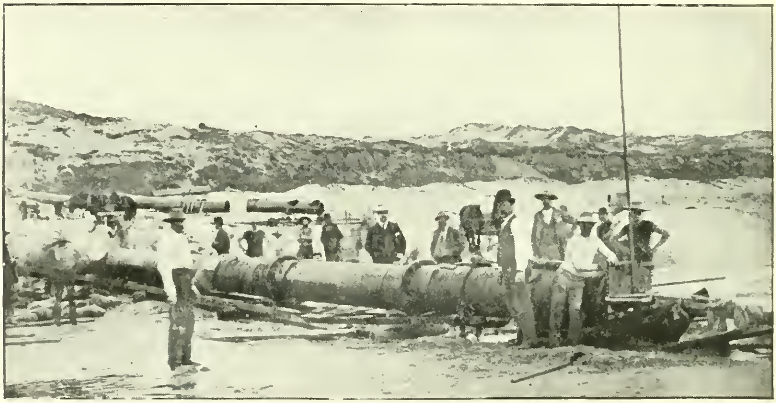
A description of sewage irrigation along the line of the Outfall Sewer, and as conducted by the South Side Irrigation Com-

FIG. 1.
WOOD-STAVE PIPE CONSTRUCTION ON SECTION 3.

Fig. 2.
Blow-off on First Siphon.

FIG. 3.
IRRIGATING HYDRANT.





Figs. 4, 5 and 6.
Launching Cast-iron Pipe.

pany and at the sewer farm of the city of Pasadena, will probably be of interest to irrigators and to those directly entrusted with sewage disposal.

The following acreage was irrigated along the line of the Outfall Sewer during the past two seasons:

In the district west of the settling-chamber, about four hundred acres. In the vicinity of structure 19½, four hundred acres. Lands reached by Lateral No. 1, three hundred and fifty acres. In the vicinity of structure 44A, four hundred acres. Total, fifteen hundred and fifty acres.

The total amount of sewage, used upon the above acreage, varies from eight to ten second-feet, or four hundred to five hundred miners' inches.

The first eight hundred acres irrigated from the sewer, being near the city, is devoted mainly to the raising of vegetables.

The land reached by Lateral No. 1 is planted in corn and other field crops. Of the remaining acreage in the vicinity of structure 44A, about one hundred acres is planted in potatoes and cabbage and three hundred acres in corn.

The City Engineer's reports for the years 1895-96 show that the sewer had yielded a small revenue, and it is reasonable to predict that this income will increase from year to year.

The receipts from the sale of sewage for 1895 amounted to		$3278.00
Cost of maintenance:		
Salary of Superintendent	$1000.00	
Assistants and labor	625.47	
Cleaning settling chamber, repairs, etc	512.50	
		2137.97
Net revenue		$1140.03
Receipts for the year 1896		4009.50
Cost of maintenance:		
Salary of Superintendent	$1200.00	
Assistants and labor	1675.40	
Repairs, etc	184.80	
		3060.20
Net revenue		$949.30

In 1883 the city of Los Angeles boasted a population of about twenty thousand, and was at a loss to know what to do with its sewage. In a fit of desperation it entered into a contract with the South Side Irrigation Company, above named, and obligated itself to *give away* to said company "all the sewage matter of every kind flowing through the San Pedro Street Sewer," amounting to 3.585

second-feet, or 180 miners' inches, and the right to use the same for a period of eighteen years.

In October, 1895, a second contract was made with the same company, whereby the city agrees to deliver 120 inches more for a period of six and one-half years, or until the expiration of the former contract. For and in consideration of this last amount, the said company has laid a cement pipe, 24 inches in diameter, 6000 feet of which lies within the city limits, and becomes the property of the city at the expiration of the lease.

In addition to the three hundred inches above mentioned, said company has the first right to use an additional one hundred inches, paying the prevailing price for it. During the irrigating season, which begins about the first of April or May, the city charges $8.00 per day of twenty-four hours for an irrigating head of 100 miners' inches. This rate is changed to $5.00 for a day run of twelve hours, and $3.00 for a night run, to suit the convenience of irrigators.

The four hundred inches now flowing through the company's pipe line is used upon about twenty-two hundred acres of land, devoted mainly to vegetable gardening. After reaching the land to be irrigated, the sewage is conducted from place to place by means of ordinary open earth ditches. This land now pays an annual rental of $12.00 per acre for river water irrigation, under the zanja system, and $18.00 per acre for sewage irrigation. Here is $6.00 per annum in favor of the latter. Further convincing proof of the superior value of sewage for irrigation is furnished by mere inspection of the orchards under the two systems.

This company has found, by experience, that on sandy soil, where the subdrainage is fairly good, it pays to use the sewage during the whole year. When not actually needing the sewage for irrigation, they find it better to flood the land than to permit the sewage to waste. The sandy soil acts on the principle of a strainer, retaining on its surface the coarser fertilizing matter, while the watery fluid portion passes away.

The writer recently visited the sewage farm of Pasadena, which is situated about six miles from the city in a southeasterly direction. This farm has an area of three hundred acres, is of a light, sandy loam soil, and has good natural drainage. An outfall sewer of vitrified clay pipe, 14 to 28 inches in diameter, carries the sewage to the farm, passing through the town of Alhambra.

Pasadena claims a population of about ten thousand, and there are possibly twenty-five hundred sewer connections.

There being no reliable information regarding the amount

of sewage flowing to the farm, the writer estimated it to be about three second-feet, or 150 inches.

Of the three hundred acres, one hundred and forty are in grain and have never been irrigated. Sewage has been used upon the remaining portion, cultivated as follows: Walnut orchard (four years old), sixty acres; alfalfa, twenty-five acres; corn, twenty-five acres; vegetables, potatoes, pumpkins, etc., fifty acres.

This farm has been self-sustaining, the cost of maintenance and revenue being each about $2500 per annum.

The public mind is greatly prejudiced against sewage irrigation, and that this prejudice is due to ignorance rather than to any harmful effects of the process, cannot be successfully denied. The objections made are always fanciful rather than real.

With a very few exceptions, there seems to be no valid objection to the use of sewage for the irrigation and growth of all kinds of agricultural products.

A great deal of "learned nonsense" has been written by theoretical engineers on the subjects of purification of sewage and sewage disposal. The writer believes the experience, here recorded, of successful and profitable sewage irrigation to be a convincing demonstration that the true solution of the problem of sewage disposal for inland towns lies in the application of sewage to irrigation.

In closing, the writer wishes to acknowledge his indebtedness to Mr. C. F. Derby, superintendent of the Outfall Sewer, and to Mr. Henry Martz, president of the South Side Irrigation Company, for courtesies extended.

DISCUSSION.

Mr. James D. Schuyler.—There are so many novel and interesting features in the construction of the Outfall Sewer here described, that the paper must be regarded as a valuable contribution to the literature of engineering on a subject of general interest to the profession.

While the general plan and details of the sewer are subject to criticism, the work cannot be pronounced a failure by any means, as it has a minimum grade of 6.6 feet per mile, and cannot fail to carry the sewage delivered to it, up to its maximum capacity, which does not yet seem to have been reached. In all portions of the work where ordinary, every-day construction details were employed, such as the brick conduit, sewer manholes, brick and concrete-lined tunnels, etc., the workmanship appears to be fault-

less, and it is only in such details as are somewhat out of the usual order that difficulties were encountered pointing to partial failure, as indicated in the paper, viz: in the sand-box or settling chamber; the so-called irrigating hydrant; the "blow-off" (a very remarkable feature to introduce in any sewer, and particularly remarkable as here designed, standing high above the surface and pointing upward like a cannon to fire at the moon); the butterfly throttle valves, which appear to have had no useful purpose, and like the other novelties have been abandoned; and the terminal outfall pipe. As described in the paper, the latter, a cast-iron pipe, originally delivering the sewage into the ocean at a depth of twenty feet, has been broken and partially destroyed, owing to lack of proper protection from ordinary wave action and ocean shore currents. It is difficult to conceive how this pipe could have been expected to take care of itself, laid as it was on the surface of the sloping beach, on unstable sands, without any sort of anchorage to hold it in position. A few iron piles on each side of the pipe, sunk to safe depths, would have kept it in line, and, while the littoral currents might have undermined the pipe by washing the sand from under it, there would have been a somewhat greater probability of security had such piles been driven. The very slight flexibility given to the pipe by the rubber gaskets in the flanged joints would perhaps have been insufficient to have kept the pipe from breaking by local undermining, even had it been kept in line in the manner described, and some of the standard forms of ball and socket joint would appear to have been preferable for this service.

In view of the conspicuous success that has been achieved in the disposal of sewage by irrigation in the European cities, as well as nearer home, the policy of constructing an outfall sewer to the ocean must be regarded as a questionable one, particularly in a country where the soils and the climatic conditions are all so extremely favorable for successful sewage disposal. Within five miles of the city limits a sewage farm could have been secured on land otherwise valueless, because of the very conditions which would render it specially desirable for sewage disposal, viz: a dry, light, porous, top soil, and open, gravelly subsoil affording ready drainage for the effluent. The cost of such a disposal of the city sewage would doubtless have been considerably less than by the present method, and it is to be hoped that in the future growth of the city, when the capacity of the present conduit has been reached, extensions of the system may be made in the line of utilization by irrigation, and the establishment of a sewage farm under city

control, rather than in the duplication of the present sewer to the ocean.

The data given in the paper as to the irrigation from the sewer are of special interest. The total revenue from sewage water sold in 1896 was $4009.50, or $2.59 per acre irrigated, the price at which the water was sold being $8.00 per twenty-four hours' run of 100 miners' inches (2 second-feet). From these data it would appear that the average depth of application must have been about 1.3 feet during the irrigation season. The irrigation rate given by the city to its consumers directly supplied from the sewer, appears to be but 44 per cent. of the rate paid by the farmers to the South Side Irrigation Company, who deal in the article as a business and make it profitable, and one cannot but wonder why the inducement offered by the low rates should not be sufficient to make an active demand for all the sewage flowing, instead of permitting a part of it—about 300 miners' inches at this writing, May 1st—to flow to waste to the ocean. The reason is perhaps to be found in the fact that the land passed over by the Outfall Sewer is, to a considerable extent, held in large tracts, and never having had the advantage of a water supply heretofore, has not the population or the degree of development to be found in the district supplied by the South Side Irrigation Company, which is nearer the city limits, and which has been, in part at least, accustomed to a periodical supply of clean river water from the regular irrigation system of the city, and is a district of small farms.

It is interesting to compare these rates for irrigation water with those prevailing in other localities. For example, the rates under the Bear Valley Irrigation Company's system last year were $35 per 100-inch twenty-four hours' flow; in Covina last year, during an unusual scarcity of supply, as high as $65 was paid for the same volume. At $8.00 per 100 inches the cost is equivalent to about $2.00 per acre-foot. Under the Sweetwater system the present rates are equivalent to about $2.20 per acre-foot, but the company is endeavoring to raise them to double this amount. Under the system of the San Diego Flume Company, the present rates of $60 per miners' inch per annum are equivalent to $4.15 per acre-foot.

The high value ascribed to sewage for irrigation in the district supplied by the South Side Irrigation Company, as described in the paper, as compared with ordinary river water less heavily charged with the elements of plant growth, and the low price at which the city sells the sewage, lead to the expectation that the section of the country favored with so cheap and so valuable a

water supply will not long permit any of it to flow unused to the ocean, and that the demand will, within a short time, keep pace with the supply.

The thanks of the society are due to the author for this entertaining paper, and engineers generally will recognize the fact that a lesson of "how not to do it" is quite as acceptable and instructive as one teaching the reverse.

Mr. H. Hawgood.—The work of which Mr. Bassell's paper treats is one of more than ordinary engineering interest, the use of inverted siphons of over three miles in length being a marked departure from usual sewer construction, and the same may be said of the wooden stave pipe used in this manner. Mr. Hy. Dockweiler and the corps of engineers who so ably assisted him in the design and construction of the works are to be congratulated upon the generally satisfactory result of their labors.

It is to be hoped that the discussion will bring out more details as to the experience of operating these long inverted siphons, particularly as regards the movement through them, or lodgment, of sand, stones and other substances.

The stripping of the $\frac{5}{8}$-inch nuts, mentioned by Mr. Bassell, is in keeping with the general experience of iron-workers; that an ordinary laborer, with an ordinary wrench, can, and usually does, strip or twist off any bolt less than $\frac{3}{4}$-inch diameter. For this reason it is good practice to use nothing less than $\frac{3}{4}$-inch diameter wherever bolts are to be tightened by other than skilled mechanics.

In the matter of vents below the straightway valves, there can be no question as to the utility of the one introduced below structure No. 44A, the outlet of the inverted siphon being five or six feet *below* the gate; but, at structure No. 19½, where the conditions are reversed and where the outlet is some five or six feet *above* the gate, the use of a free vent is questionable, and it would be of interest to hear the reasons that governed its adoption. The paper does not furnish data for anything more than approximate calculations, but it would appear that, with a full sewer and with the gate closed instantaneously, the stored-up energy of the moving body below the gate (in the inverted siphon) would be about 1,880,000 foot-pounds and, before the mass had been brought to rest by the opposing head and friction, some three to four hundred feet of sewer immediately below the gate would have been emptied. This distance will, of course, be reduced by decrease in quantity of flow through the sewer and by slow closing of the gate. After a momentary pause, the water will fall back into this empty space, and, meeting with sudden stoppage at the gate, will cause a severe

"hammer-blow" and great strain on the sewer, as evidenced by the articles mentioned by Mr. Bassell as being ejected from the vent pipe. Undoubtedly, a formidable quantity of accumulated work is suddenly and violently dissipated, to the danger of the sewer. If a vent is used, it certainly should be furnished with a valve, which, while giving free ingress to the air, would check its egress sufficiently to form an efficient air cushion and bring the returning water gently to rest.

In place of a valve, with the resulting complication, it would probably be better to provide no vent, and to arrange for a positively slow closing valve. Any tendency to the formation of a partial vacuum below the gate tends to increase the effective head opposing the movement of the water column, and at the same time increases the discharge through the gate opening to destroy the vacuum. Properly carried out, it would subject the sewer to no greater strains than a controlled vent, and certainly less than the present free vent. Parallel cases are to be found on almost every large water main.

In regard to the breaking of Lateral No. 1, I can speak advisedly as to the causes of failure, having been called in to advise as to repairs. The primary cause of failure was weak design. The sides of the aqueduct were of insufficient strength to resist bursting with a full conduit, even with a perfect bond between the sides and floor, and in many places this bond was imperfect, for the arch ribs of the structure formed a channel under the floor. The form which filled this channel, and which formed part of the mold for forming the concrete was of wood. The wet concrete swelled the wood, and that, in its turn, thrust upon the sides and prevented any bond between sides and floor. In the rebuilt structure this danger was avoided. The hooping of the structure with rails was to strengthen work built under the original design, that had not actually failed, but was dangerous under a full head. The concrete specified as 7 to 1 was good, for that mixture; showing a crushing strength of over nine hundred pounds per square inch.

Mr. D. C. Henny.—The design of the details of the wooden pipe siphons deviated from ordinary wooden pipe practice. *First,* in the use of wooden instead of metal tongues for connecting the butt-ends of the staves; *second,* in the form of the shoes uniting the ends of the steel bands: and, *third,* in the absence of an upset and in the fine thread on the bands.

The first deviation seems objectionable, because the comparatively great thickness of the wooden tongue precludes the possibility of indentation at the bottom of the groove. The depth of

the groove must therefore be exactly one-half the width of the tongue, in order that the staves may butt up tight and at the same time the groove be completely filled by the tongue. Such exact fit is not uniformly possible with ordinary wood-working machinery, and the tendency is to have the slot too deep, in order to insure the solid butting up of the staves. Thus the hard contact at the bottom of the groove, caused by positive indentation of a metal tongue, is not attained; and, moreover, vacant spaces may be left, back of the tongue, which in themselves are objectionable, as they may cause leakage by being filled from the inside at one point of accidental defect, and may connect with the outside at another such point. The thick projections of the tongues beyond the edges of the staves may also prevent the adjoining staves from coming to as perfect a bearing as is desirable, at least where the spacing of the bands is wide. It appears, however, that no trouble has resulted from this cause.

As regards the second deviation, the objectionable features of the form of the shoes have been pointed out by the author. By adding length and thickness, this form of shoe can undoubtedly be made strong enough to resist the torsional strain to which it is subjected, but the writer has never seen any shoe of this type where this had been done to a sufficient extent. In the case under consideration, this weak point became more apparent, as the material used was common cast iron. Malleable iron or steel is preferable, for no shoe can be designed in which a portion of the metal is not in tension.

Respecting the third point, the writer holds that great waste results from cutting the threads on pipe bands, instead of rolling them on, or instead of previously upsetting the ends. It was probably with a view to reducing this waste that a much finer thread than the standard was used. Experience has evolved certain proportions of threads, in harmony with average accuracy of shopwork, and merely theoretical reasons hardly justify one in departing from these proportions. That frequent stripping of threads occurred in cinching, as stated by the author, was not surprising. With good work in rolling or cutting threads and tapping nuts to standard proportions, continued turning of the nut will, in the large majority of cases, result in rupture of the bolt by the combined effect of pull and torsion, and not in stripping of the thread.

Considering that the points of greatest depression in the two inverted siphons are but twenty-seven and twenty-five feet respectively below the hydraulic grade line, and that the fluid carried was

FIGS. 7 AND 8.
BREAK IN LATERAL NO. 1.

sewage and not clear water, the leakage that was first experienced after filling, and which necessitated the subsequent digging up of most of the entire pipe line, was a surprise to the writer. It is true that both the contractors and their men lacked all experience in wooden pipe construction, but there was honest and rigid inspection on the part of the city. Whether poor workmanship was alone responsible for the result may be doubted. The author has described the butterfly valves which were placed at the lower ends of the siphons to maintain the upper ends full. Although they are stated to have leaked badly when closed, they must at such times have come near converting the hydraulic head on the siphons to a hydrostatic head, thereby increasing the head on the lower ends of the siphons about twenty-five feet. The bands on the pipe were not spaced sufficiently close for this additional head, even neglecting the serious water hammer which might be looked for from the operation of these gates.

The use of butterfly valves on long pipe lines with high velocities is, in the writer's opinion, radically wrong, as it usually permits too rapid operation and the valves cannot be made tight. Possibly the author can give some information on the occurrence of water hammer at the time these gates were in use. The slide valve, besides being tight, has the advantage of being more readily adapted to extremely slow motion. The quick closing of gates should be a physical impossibility on long pipe lines with high velocities of flow, for it is far better to prevent serious water hammer than to attempt to neutralize its evil effects by automatic devices. An open air vent, back of a main gate, is very desirable, but it should not be depended upon to render too rapid obstruction of flow harmless beyond preventing collapse.

The location of the new slide valve gates on the upper stretches of the siphons approximately on a level with the outlets, is preferable to that of the old butterfly valves at the outlets themselves, as they attain the same object with a minimum increase of pressure on the pipe when closed.

Before the system was put in operation some fear was entertained lest the sediment formed in the pipe at times of small discharge would not be flushed out at times of maximum discharge. The writer understands that there has been no trouble in keeping the pipe clean, but, in view of the author's statement that the settling basin at the upper end permits the bulk of the suspended matter to pass on, some definite information on this point and on the maximum velocity of flow, at present available for flushing, would undoubtedly prove of interest.

Mr. Gervaise Purcell.—Being unfamiliar with the details of the Outfall Sewer, I am unable to give an opinion as to the justness or unjustness of the criticisms, as local circumstances have to be taken into account.

On the use of sewage for farm purposes, where the land is suitable or has been suitably prepared, I have always been a strong advocate of broad irrigation, feeling that the experiences of the sewage farms of Berlin and other cities of Europe, place it beyond the pale of experiment.

In November of 1894, I was consulted by the city of Pasadena as to the best way to remodel its sewage farm so as to abate the nuisances into which it had drifted, and to make it self-sustaining if possible. Hence I am able to verify the author's statement as to its present condition, only correcting him so far as to say that last year it showed a balance in its favor of $600; and, as the walnuts come into bearing, this balance will increase from year to year. I found that, to make the sewage flow freely, so as to be kept in sufficient motion to prevent stagnation, which might create a nuisance, it is necessary, in this climate, to dilute the sewage with an equal amount of water, and that this is best accomplished in the main conduit as it flows to the farm. The author is in error as to the amount of sewage, it being only half a cubic foot per second for the three thousand connections reported. This, with as much water added, gives a constant summer flow of one cubic foot per second. It was liberally prophesied that the product of the farm would never find a market, but, as a fact, from the first the demand has exceeded the supply.

Mr. Grunsky (Temporary Chairman).—The use of an inverted siphon on a large scale, in connection with a sewerage system, has been brought out very nicely and clearly in this paper. Notwithstanding that mistakes were made in some of the details, the entire system seems to be operating fairly well.

The paper itself and the written discussions that have been read cover the points quite completely. There is, however, one thing in connection with this sewer that is not mentioned in the paper nor in the discussions. The original question presented by the city of Los Angeles to the engineers was as to the best method of disposing of the sewage, whether to carry it out into the ocean, or whether to use it for sewage irrigation. The result was that a line was so constructed that the sewage can be used for irrigation, or it can be emptied into the ocean. Either method can be used.

Mr. Allardt.—Why was not a wooden pipe used all the way? It would be cheaper than anything else, and it is strong and admits of a very rapid current.

Mr. Henny.—There were places that required a stronger material than wood, and in such places they used other material.

Mr. Allardt.—Could not the grade line be made in such a manner that the pipe would be full all the time?

Mr. Henny.—Probably the depression was such that the use of a siphon could not be avoided.

Question.—Is the velocity given, or the grade?

Mr. Grunsky.—It is stated in the paper in a general way. Of course, the discharge of the sewer is variable, as a large amount of sewage is sometimes used for irrigation.

Mr. Henny.—I think the system has been laid out for a much larger flow than there is at present.

Mr. Wagoner.—Has there been any trouble with leakage in the wooden pipe portion of the sewer?

Mr. Henny.—There was some leakage, which seemed to be all along in the seam joints; possibly more where the butt joins than elsewhere. The general cause of leakage was in not cinching the hoops sufficiently tight. The castings would break, and there was stripping of threads when the hoops were cinched tightly, and this extra expense the contractors did not like to bear, not seeing the actual necessity of it.

Mr. d'Erlach.—You stated, I believe, that the hoops were some distance apart?

Mr. Henny.—I think about twelve inches—possibly ten inches.

Mr. Allardt.—Would not the acids in the sewer hasten the rusting of the iron hoops if it percolated through the wood? It is more corrosive than pure water.

Mr. Henny.—Of course, the wood will act to a certain extent as a filter. The percolation through the wood would be very small. As to the condition of the sewage after it had filtered through an inch and a half of wood, I am not prepared to say.

Mr. Allardt.—The corrosive action would be a great deal more than if it were pure water.

Mr. Henny.—There would be more acid in it.

Mr. Storey.—Was this sewer constructed on the idea that it was an improvement on the general plan pursued in other systems?

Mr. Henny.—Yes; but I would not be understood as saying that it would not have worked properly under other systems.

Mr. Storey.—I do not see why it should work any better than other methods.

BRADLEY & POATES, ENGR'S N.Y

PLATE 1

MAP
OF THE
Outfall Sewer
Of the City of Los Angeles, Cal.
J.H. Dockweiler, City Engineer.
Scales
Pacific Ocean
City of Los Angeles
Inglewood
Hyde Park
SECTION 1
SECTION 2
SECTION 3
SECTION 4
SECTION 5
SECTION 6
SECTION 9
LATERAL No. 1
LATERAL No. 2
LATERAL No. 3
END OF LATERAL No. 1
END OF LATERAL No. 2
END OF LATERAL No. 3
BEGINNING OF LATERAL No. 1
BEGINNING OF LATERAL No. 2
BEGINNING OF LATERAL No. 3
T2S R14W
T3S R14W
T3S R15W
T2S R13W
T3S R13W
VERNON AVE.
Note
Miles denoted thus

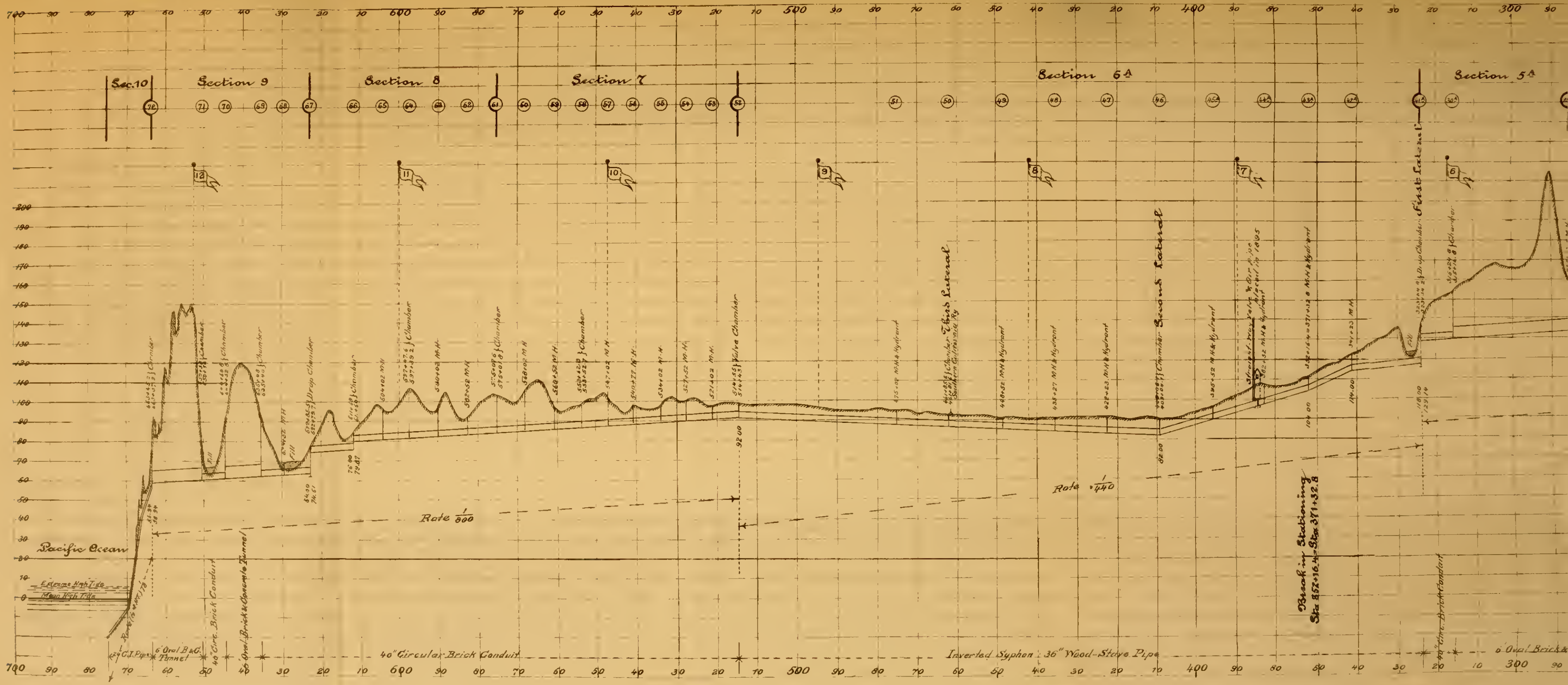
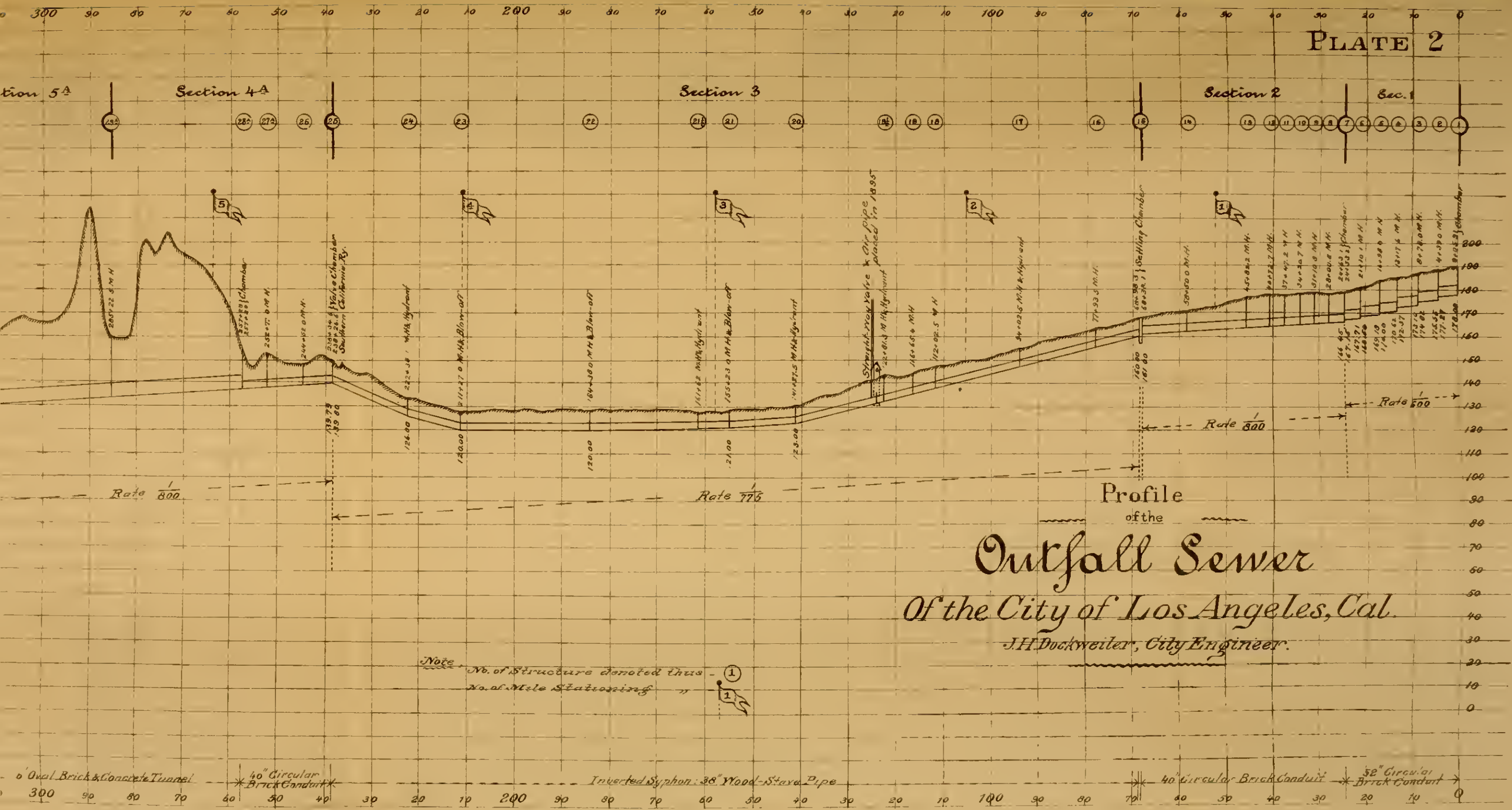
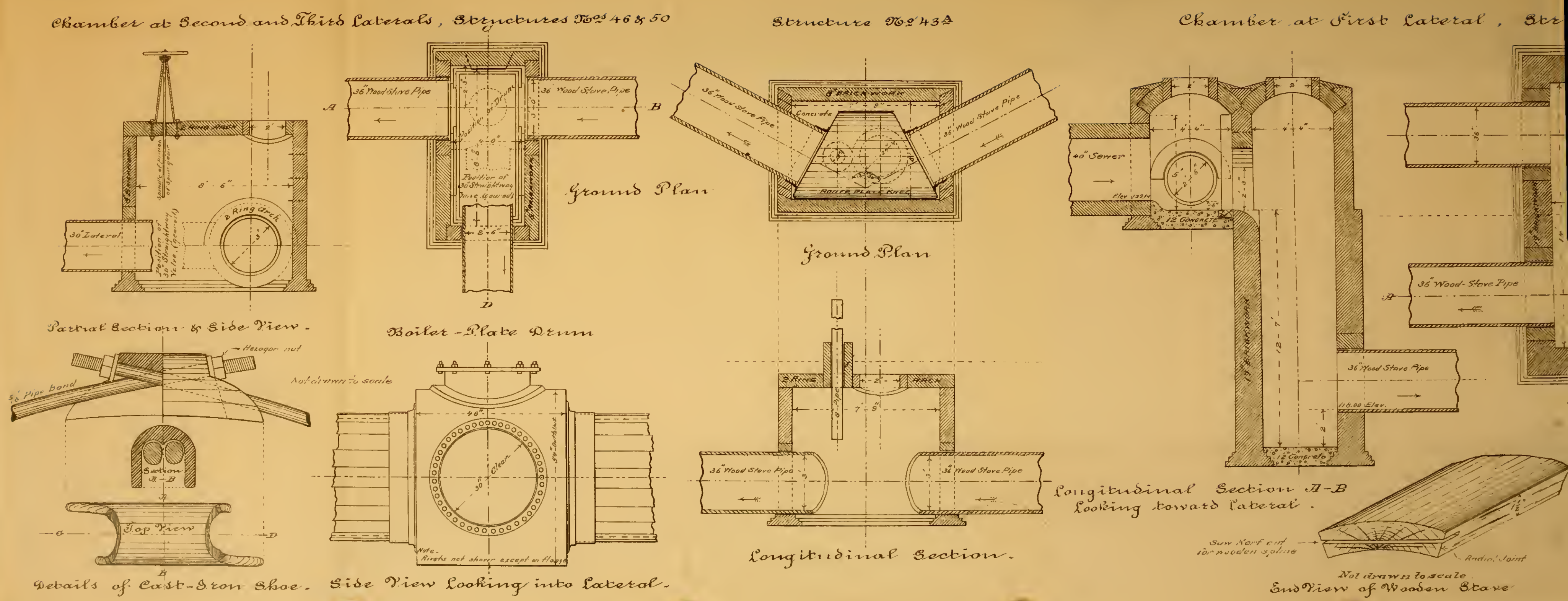

Sec. 10
Section 9
Section 8
Section 7
Section 6A
Section 5A
Pacific Ocean
Extreme High Tide
Mean High Tide
Rate 1/800
Rate 1/440
Valve Chamber
Third Lateral
Second Lateral
First Lateral
Drop Chamber
Break in Stationing Sta 852+16.4 = Sta 371+32.8
40" Circular Brick Conduit
Inverted Syphon: 36" Wood-Stave Pipe
6' Oval B & C. Tunnel
40" Circ. Brick Conduit
6' Oval Brick & Concrete Tunnel
40" Circ. Brick Conduit
6' Oval Brick &
Fill
92.00
92.00
700
600
500
400
300

PLATE 2



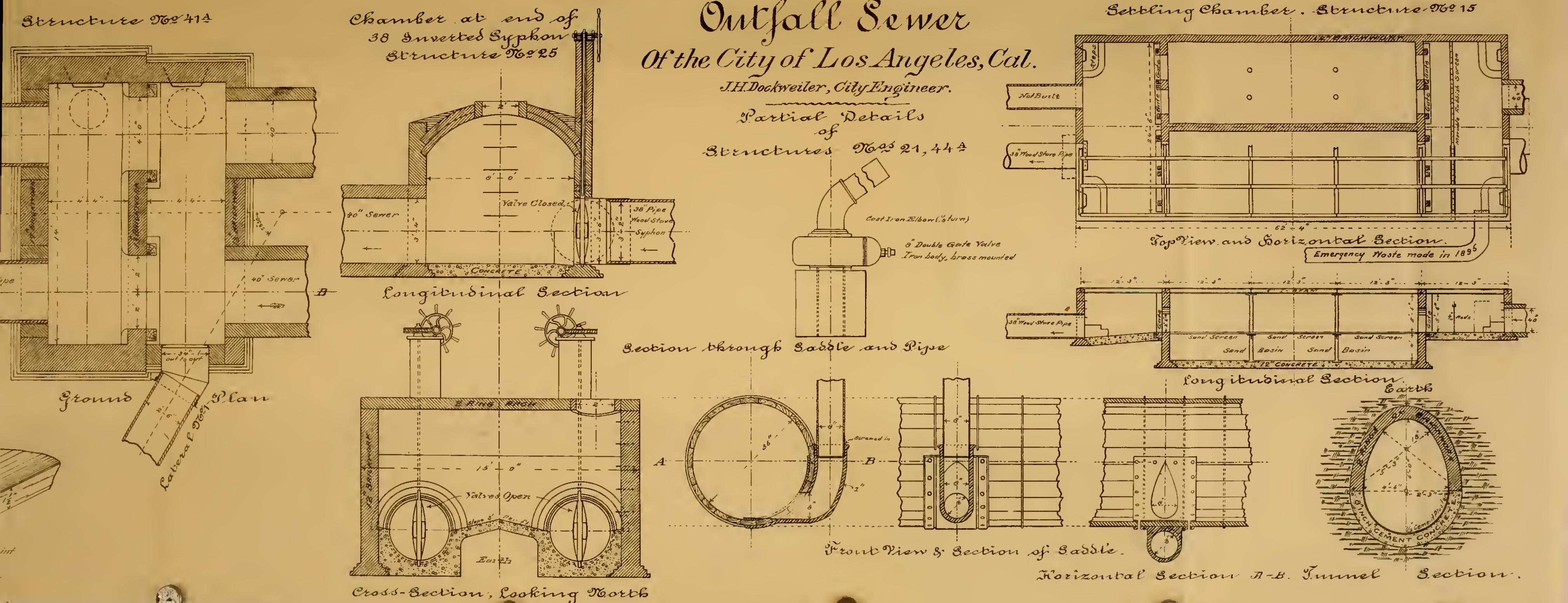
Section 5A
Section 4A
Section 3
Section 2
Sec. 1
Rate 1/800
Rate 1/775
Rate 1/800
Rate 1/600
Profile
of the
Outfall Sewer
Of the City of Los Angeles, Cal.
J.H. Dockweiler, City Engineer.
Note. No. of Structure denoted thus (1)
No. of Mile Stationing "
Oval Brick & Concrete Tunnel
40" Circular Brick Conduit
Inverted Syphon: 38" Wood-Stave Pipe
40" Circular Brick Conduit
52" Circular Brick Conduit
Settling Chamber
Valve Chamber
Southern California Ry.
Straight-way Valve & Air pipe placed in 1895


Chamber at Second and Third Laterals, Structures Nos. 46 & 50
Structure No. 43A
Chamber at First Lateral, Str
36" Wood Stave Pipe
2 Ring Arch
8' 6"
30" Lateral
Position of 30" Straightway Valve (geared)
2 Ring arch
Partial Section & Side View.
Ground Plan
Boiler-Plate Drum
8" BRICKWORK
Concrete
BOILER PLATE RIVET
Ground Plan
40" Sewer
12 CONCRETE
17" BRICKWORK
12' 7"
116.00 Elev.
12 Concrete
Longitudinal Section A-B
Looking toward lateral.
Hexagon nut
Not drawn to scale
Pipe band
Section A-B
Top View
Details of Cast-Iron Shoe.
48"
30" Clear
Note. Rivets not shown except on flange
Side View Looking into Lateral.
2 RING ARCH
7' 9"
Longitudinal Section.
Saw kerf cut for wooden spline
Radial Joint
Not drawn to scale.
End View of Wooden Stave

PLANS of the Outfall Sewer Of the City of Los Angeles, Cal.

J. H. Dockweiler, City Engineer.

Partial Details of Structures Nos 21, 44A



ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIX. SEPTEMBER, 1897. No. 3.

CONDUITS AND CABLES.

BY ALEX. DOW, MEMBER DETROIT ENGINEERING SOCIETY.

[Read before the Society, December 18, 1896.*]

A CONDUIT may be defined as a passage or subway for containing electric wires, underground cables, or the like. In a more limited sense, a conduit is a tube or channel into which such conductors may be placed or drawn, but which is not itself accessible for inspection or repair of the conductors, as distinguished from a subway, into which access can be had at any portion of its course.

An instance of a conduit in the narrower sense is a tube, having manholes at different points along its length, the conductors being pulled into the tubes by ropes passing from one manhole to the other; while an instance of a subway would be a tunnel of dimensions to admit of the free passage of men and of the use of tools for any of the common operations required on the conductors.

The former construction is common through the United States; the latter is exceptional, the only city where any systematic subway work has yet been completed being St. Paul, Minn., where local conditions make a tunnel construction less expensive than a conduit of any but the smallest capacity.

The history of conduits begins along with the practical use of electric telegraphs. The plans of Professor Morse included a lead pipe conduit into which an insulated wire was to be drawn,

*Manuscript received September 3, 1897.—Secretary, Ass'n of Eng. Socs.

and this construction was begun on the experimental Washington-Baltimore line, but failed almost at once through mechanical defects. Wires, strung on posts, were substituted, and were used without protest in the largest American cities, as well as along railroads and highways, until within the last few years. But on the other side of the Atlantic the public objection to the obstruction and disfigurement of the streets by posts and wires was strong enough to force a different solution of the problem, and the opportune discovery of the qualities of gutta-percha as an insulator for electric conductors presented the means; so that the first city telegraph office in London was connected to the railroad telegraph wires by gutta-percha insulated wires drawn into iron pipe, a combination which is standard for telegraphic work in Great Britain till to-day, the pipes being invariably cast-iron and the wire being sometimes, for mechanical reasons, insulated with india-rubber instead of gutta-percha.

It was very much later before the American telegraph companies were obliged to place any of their wires underground, and the experience of British and European telegraph departments was then available to guide them. Gutta-percha insulated wires were imported, and at least one factory for the making of such wires was established here; but by this time the manufacture of india-rubber had been developed to such an extent in the United States that cables insulated with this latter material could be produced cheaper than those of gutta-percha, and so became standard, as far as anything (with one notable exception) ever has become standard in American cable practice.

The introduction of electric lighting, twenty years ago, brought with it a new set of conditions. The amount of power to be carried by an electric lighting conductor was infinitely greater than that on any telegraph wire. The heating effects of large currents, which were entirely unknown in telegraph practice, had to be considered; and the fact that electrical supply had to be furnished to a large proportion of the buildings in a city introduced problems as to connections and branches which were radically different from anything found in telegraphic work. It is evident that a system of telegraph cables to connect with four or five, or possibly a score of offices, in one city was a very different thing from a system of electric lighting cables to connect with several thousand different customers. This last condition was at first much the most difficult to meet, because neither the stress due to high electric potential nor the heating due to large currents was, in the earliest electric lighting, much beyond

the limits which had been reached in telegraphic work; indeed, in England, some early distributions of electric light were made with entire success through conductors insulated with vulcanized india-rubber, after the same specification as conductors for telegraph purposes. In these instances the pressure was not in excess of 100 volts.

The development of cables and conduits in British practice has been mainly on the line of telegraphic work, and even in this present year electric lighting plants are being installed in Britain in which the cast-iron pipes forming the conduits have been furnished under specifications identical with those used by the British Post Office for pipes for telegraph purposes, and the rubber-insulated cables differ only from the wires furnished to the post office in having greater cross-section of conductor and increased thickness of the rubber walls.

But in the United States the public had been educated into the toleration of overhead wires, and our cities were disfigured within five years with a forest of posts and a network of aërial conductors more extensive and more offensive than all the telegraph wires strung in the preceding forty years. Only one electrical inventor, Mr. Edison, spared the time to design a complete system of buried conductors for electric lighting currents, and only the Edison lighting companies were willing, under his advice, to meet the expense of laying down complete underground distributions. The system Mr. Edison designed fulfilled admirably the requirements I have just stated, and, most admirably of all, that of permitting, without interruption of current or weakening of insulation, the frequent connections of service wires for customers. How much this design was in advance of current practice is shown by the record in this city, where the Edison mains laid in 1886 have remained in continuous service till to-day, while no other electrical supply company has yet constructed an effective system of underground mains, and the city's underground mains for street lighting were only put in service last year.

In the lighting department are to be found the greatest variety of conduit and cable constructions and the most complete absence of a standard practice. Even the Edison companies in these latter days have followed strange prophets. Very false prophets, too, have some of them been.

The telephone followed closely on the electric light in its early development, and it also had its period of overhead wires and street obstruction and disfigurement. It has, however, redeemed itself early in the day, and the gigantic poles, carrying

hundreds of telephone wires, have disappeared from the business districts of all our large cities.

Telephone practice in cables and conduits was at first a copy of the existing telegraph practice, but the scientific study of the telephone carried on under the auspices of the Bell Telephone Company has led to a differentiation in the direction of the use of cables better suited electrically to telephonic currents of small volume and of very high frequency, and better suited mechanically to the conditions which require many thousands of independent conductors to be concentrated within the smallest possible area in the conduits leading to a modern telephone exchange. This is the notable instance of standardization to which I have previously referred.

The modern telephone cable, called the "conference cable," represents the practical experience, the laboratory experiments, and the mathematical calculations of as competent a corps of engineers as can be found in the United States to-day.

To give a history of all the developments of my subject is a task that is far beyond the limitations of a paper like this. The best that can be done is to describe the practice of the present day and to state shortly the reasons of this practice.

Conduits for all systems of electric distributions are governed alike by some conditions. They must, in common with all underground structures, be of material that will not decay in the presence of moisture and of the various destructive agents found in the soil. Among these destructive agents are included the illuminating gas with which the subsoil of most of our cities is saturated, the leakage from sewers and cesspools, and the electrolytic action of the return currents of the street railway system. Further, the conduit must resist the settling of the soil and the bad usage by careless laborers which accompany the frequent excavations made in city streets. Lastly, it must be intersected at convenient points by distributing chambers, commonly called manholes. In addition to these *absolute* requirements, the conduit should preferably be drained and ventilated, so that there will not be in it any accumulation of water or gas to interfere with the operations of workmen having business with the cables. In a system designed to be water- and air-tight these latter requirements are not necessary, so that I have indicated them as desirable rather than absolute conditions. You will notice that I say "water-tight and air-tight." It has been frequently assumed by inventors, and occasionally by skilled constructors of conduits, that a conduit might be made water-tight

without being absolutely air-tight. I am satisfied that if the former condition is sought, both must be secured, because air carries with it a certain amount of moisture and will, on a reduction of temperature, deposit that moisture on any hygroscopic surface with which it is in contact. In my experience I have never seen a water-tight or so-called "weather-tight" construction, not also air-tight, which did not sweat very badly, and even sealed junction boxes and switch boxes, which are only occasionally opened to the atmosphere, will be found to suffer to a slight extent from the same trouble.

It is in order here to discuss the differences between the two classes of conduits,—those which are intentionally made air- and water-tight, and the much larger class in which there is no special endeavor made to secure tightness. The first class is usually an insulated conduit,—that is to say, the conduit construction is itself of insulating material and the conductors are either bare or only covered for mechanical reasons. The insulated conduit has been a dream of hundreds of electricians, and has been sought for persistently from the earliest days of the telegraph. I believe that but two systems have yet been developed which have stood the test of time and can now be classed as successes. The first of these is much in use in England and, to some extent, on the continent. It is not the production of any one inventor, and although many of its details, as used in different installations, are covered by patents, the method as a whole is open to any user and details of a practicable kind can be designed by any good engineer. It is generally known as the "Crompton" system. A conduit, usually of concrete, but sometimes of brick or iron, is constructed in lengths as long as convenient, subject to the limitation that each length must be straight in both the horizontal and the vertical plane. In this conduit are placed porcelain insulators of a saddle or tube shape, over or through which are drawn copper rods or strips. At each change of direction, and at intervals in any straight run of exceptional length, small vaults are built, having air-tight covers, and in these vaults clamps to grasp firmly each conductor are placed, and a screw and nut or equivalent device attached to each clamp wherewith to strain the conductor, so that it does not sag between insulators. In some instances automatic devices are used for taking up any slack due to heating of the conductors, but the more common practice is to apply sufficient initial tension to prevent the copper sagging to a dangerous extent under the maximum heating that is to be allowed.

I do not know that this method has ever been applied to

conductors having a potential difference greater than 500 volts. Its continued use proves that it must be a success, but it has developed some characteristic faults. First, there is the sweating, which I have already mentioned. The air trapped in the conduit will, on a fall of temperature, deposit its moisture on the porcelain insulators, and the wooden blocks on which these insulators have been mounted are found in time to become saturated with water. This produces a state of permanent dampness in the conduit, causing a slight general leakage of current, and if the trouble stops at this there is little fault to find, as in the low-tension systems such a leakage is not very expensive.

But the gases which saturate the soil also find entrance to the conduit, and the distilled water of condensation absorbs these gases, so that the leakage is aggravated by the change from *aqua pura* to an aqueous solution of one or more objectionable chemicals, and surface leakages of large quantity become normal, with electrolytic deposition of copper salts on the porcelain. It was believed at one time that the porcelain surface was permanent, but now one user of this system is seriously considering the abandonment of it entirely, because of the impossibility of cleaning or replacing the porcelains as frequently as is required, and because the compounds electrolytically formed are held to have been responsible for explosions of the mixture of air and gas in the conduit.

The other system which has proved a success is one developed by a Detroit inventor, Mr. Cummings. He placed on the market some four years ago tubes into which bare copper conductors could be drawn readily, in lengths up to 300 or 400 feet, and of sizes up to 1 square inch of cross-section. To about $\frac{1}{6}$ of a square inch these conductors may be round copper rod, the size known as 4–0 Brown & Sharp gauge being frequently used. Above that cross-section the conductor must be stranded. The tubes are made both single duct and multiple duct, as many as seven ducts having been used in local practice. The outer tube is iron, usually being standard weight steam pipe. The ducts are wooden tubes, the wood being treated with creosote or some similar preparation in order to secure durability. In the single duct form for low voltages the wooden tube is directly in contact with the iron tube, but when the single duct is used for conductors of higher electro-motive force, and when multiple ducts are used, the wooden ducts are served with cord, which acts as a mechanical separator from the iron pipe and also to separate one duct from another, and the interstices are filled with a mineral product,

such as asphaltum or tar. The material at present used for filling is one of the petroleum products. These completed tubes are butted together, end to end, the exact coincidence of each duct with its continuation in the next tube being secured by very simple means, and this butted junction is made water- and air-tight by clamping around it a cast-iron box, which is filled with compound similar to that used in the tubes. The manholes or junction boxes of this system are iron castings, with loose outer cover and an inner cover which is made tight by a rubber gasket and an application of hot beeswax and tallow.

The Cummings system has a number of advantages peculiar to itself. The wood surface of the duct is not hygroscopic, so that no condensation takes place except on the sides of the iron manholes, where it does no harm.

The coefficient of friction between copper and the prepared wood is very small, so that there is no trouble in pulling a great length of heavy conductor. Then the material seems to be permanent in its electrical and mechanical qualities, and it is of necessity used of considerable thickness, so that there is no possibility of conductors in different ducts being brought within the sparking distance of any ordinary voltage. I don't think that the makers of this conduit will err as did the cable manufacturers in placing cables on the market which gave a high laboratory test, but infallibly punched out under the practical conditions of use.

There have been several attempts made by manufacturers of paper-lined tubes to introduce these into service as underground conduits. So far I do not know of any permanent success. There was one very rank failure in this city, of which most of you who observe such things are probably cognizant. A conduit system was laid of paper tubes stacked in a box filled with roofing tar and having manholes which were *supposed* to be water- and air-tight. Into the tubes were drawn wires braided or lightly insulated with rubber tape. It was a mistake to insulate the wires at all, because the braiding received moisture from the air at each reduction of temperature, and held it in contact with the paper of the ducts. The surface of the paper was moisture-resisting, but the material was not so saturated as to be permanently damp-proof, and in due time there were frequent failures of insulation and burning of the conduit. Please note that it is a good thing (other things being equal) to have your duct material fireproof, because if anything does go wrong with an electric light conductor a blaze is the usual consequence. The troubles which were

incident to the design were aggravated by the carelessness of the builders, who made many connections into the manholes in a rough-and-ready way, which was certain in time to allow the entrance of water to these manholes, and from them to the tubes. Finally the system, after suffering still more from neglect of men who should have taken care of it, was abandoned altogether.

I don't know any reason why a paper tube system should not be brought into practical shape. It is still being exploited occasionally by one tube manufacturing concern, and they may ultimately make it a go. Their circulars, however, distributed within the current year, show a lack of appreciation of the practical conditions of conduit work which prevents my hoping for an early success.

There is a tight system occasionally used which deserves mention, although its limitations are such as to prevent its general adoption. It is the Brooks oil-insulated conduit. In this method an iron pipe is laid and made tight. Into it the conductor, wrapped with a fibrous covering, such as jute, is drawn, and finally the tube is pumped full of heavy oil, such as resin oil. Arrangements are made so that a pressure of a few pounds to the square inch is maintained on the oil, so that there is no tendency for water to leak in and displace it. A very perfect system of glands and packing has been devised for service connections and terminals. The chief claim made for this system is that the oil prevents the development of a permanent fault sequent to a high-tension discharge from the conductor to the iron pipes. Experience in this country with oil-insulated transformers would justify this claim, but it is doubtful whether under any usual conditions the complications of the system would be warranted in order to secure this special advantage.

Coming now to the much more common conduit systems, which are neither tight nor insulated—which are tersely described by a practical man as "horizontal holes in the ground into which you can pull cables"—the tendency to-day is to accept as standard for all classes of electrical work a duct of vitrified brick or terra cotta. There is a strong minority opinion in favor of a duct called "cement-lined," molded within a sheet-iron shell from a mixture of Portland cement and sand,—an artificial stone. The fault of the latter is its very high coefficient of friction in conjunction with the usual lead sheathing of cables, which makes the pulling of the cable through a cement-lined duct a much greater undertaking than through an equal length of tile. The advantage of the cement-lined duct is that it can be produced in greater

lengths than is possible with tile or terra cotta, because of the warping of the latter in the kilns.

Ducts of asphaltic concrete were once used, these having been the earliest in the market, and, having been cleverly exploited, were laid down in many cities, including Detroit. They were expensive, which is their chief fault. The minor faults were liability to damage from the burning out of a cable and from proximity to steam pipes or other sources of heat to be found under city streets.

The tile ducts are made both single duct and multiple duct. Both the Camp single duct tile and the McRoy multiple duct terra cotta conduit have been largely used in this city. For multiple duct conduit the Camp tile is laid in tiers in cement mortar exactly like bricks in a wall, the matching of the ducts being secured by drawing a mandrel into each tile as it is laid. The McRoy conduit is usually laid the same way, but sometimes, when it is important to exclude water, the joints between sections are sealed by a wrapping of jute bagging, saturated with hot asphalt. This is an old plan, having been used with the Lynch conduit, which was a tile of square cross-section (usually 10 x 10 inches), having a horizontal partition, which carried one layer of cables, while a second layer rested on the bottom of the tile.

The standard duct for telephone purposes is 3 inches in diameter, and electric light men are finding this also a convenient size, so that it is now the most frequently called for. It holds three or four small cables or one large one, or a multiple conductor feeder cable for a three-wire system, very conveniently.

Manholes are almost always built of brick. When a fairly large manhole is needed it is hardly possible to use anything but brick. Cast-iron manholes of small sizes can sometimes be placed, but the inflexibility of this material makes it very inconvenient when the street is crowded with pipes and conduits having prior right of way. I have seen and used concrete manholes, some of them of large size, but the same difficulty affects these, as they must be rammed up around a mold, which mold cannot be placed in position if there is any obstruction in the hole. If you have to build a new mold for every hole, there is no profit in concrete work; but with brick you can build the manhole of any shape required, and you may write it down that no two manholes in a city job built in these latter days will have the same dimensions, and you will be fortunate indeed if one-half of them are so nearly of contract shape that the contractor will not claim "extras" on them.

The sewer connection is necessary in manholes frequently used. Those seldom opened and far from sewers may be allowed to fill up with water, if the cables are of the lead-covered type, as pumping out occasionally will be cheaper, in the long run, than sewer connections. Ventilation sufficient for the dilution of gases to a safe figure can usually be had by perforation of the manhole cover, but where much gas leaks in, special provision for ventilation should be made.

The best practice, as exemplified in recent work, is to lay the tile conduits on a foundation of concrete and to fill the space between the stack of tiles and the sides of the ditch with grout. The use of the foundation is obvious. The side filling is preferred to back filling the earth, because it does not require to be rammed, and so the danger of displacing the tiles from their alignment is avoided. On top of the whole construction a layer of concrete is advisable, although not always necessary, its use being to protect the tile from picks and bars in the hands of careless excavators.

There is no standard practice in the construction of branches from main lines of conduits. The telephone companies commonly use sewer tile, employing the usual sweep bends for angles. The joints between the sewer tiles are made with cement mortar. Where there is risk of disturbance, or where the space for the branch conduit is limited, as it is in many alleys and courts, wrought-iron pipe is used. There is a tendency to use cast iron, which I think is preferable to either wrought iron or tile for runs of one or two ducts, in that it is neither so easily injured as the tile, nor does it rust out, nor be eaten by electrolysis, so soon as the wrought-iron pipe. Most of the wrought-iron pipe on the market to-day is not iron at all, but is steel, and it does not last underground as long even as the old-time wrought iron.

In two recent installations of single duct conduits in parks, namely: the West Park plant, in Chicago, and in our own Island Park, wooden pump logs have been used for ducts. This material, when kept constantly wet, lasts for a very long time and is a very satisfactory conduit. In soils which are only moderately damp the saturation of the wood with creosote much increases its useful life. From my experience in Chicago, I should fear that the pump log laid close to the surface, as it is in the West Park installation, will not last for any length of time, but on Belle Isle, where the soil is not only saturated with water, but where the wood has been creosoted, I think the conduit will be as durable as any other material except tile. The objection to tile is the

difficulty of joining it in a wet ditch, such as is usual on the island, the cement being washed out of the joint at once, and the certainty that tree roots, particularly those of the willow species, would find their way into the conduit and in time fill the ducts with a vegetable network, which would prevent the drawing in or out of cables. The creosoted wood is not touched by tree roots at all, and the joints, having been sealed with roofing tar, will permit no access of the suckers.

My idea of a perfect single duct system is a cast-iron pipe laid exactly as is a water main, the joints leaded and caulked and the occasional curves or large radius being obtained, as they are in water main practice, by offsetting each length of pipe a little. It would be necessary to ream out the spigot end of each length of pipe, and there should be provided plenty of flanged lengths to be used instead of the leaded joints in working through occasional wet places. The pipe ought to be thoroughly cleaned at the foundry and coated hot with Angus-Smith compound. Special sweep fittings would be used for laterals entering buildings or led up poles.

To turn from conduits to cables: In all departments of electrical work the lead-covered cable is now used. There are very few engineers laying cables not protected by lead these days. Some estimable gentlemen have been so "rattled" by the ravages of electrolysis that they have advocated a return to the use of nonleaded cables, substituting for the lead a saturated braid or tape. I have not heard anything of this idea for the last eight months, and its advocates have had the worst of it in all the arguments of the earlier part of the year. But this agitation has had the good effect of bringing about the study of the use of protective braids or coatings to be applied over the lead, and it has been found, as usual in our cable practice, that the European engineers have developed this system very thoroughly. Any of the cable companies will now furnish leaded cables having an external coating. One of the best of these consists of, first, the coating of the cable with an asphaltum compound, which does not harden in cold weather; next, the lapping around the cable on top of this coating of a double layer of dry manilla paper; third, another coat of asphaltum, of a different composition, which sets harder than the first coat; finally, two servings of jute twine, saturated with asphalt, the second serving being applied in the reverse direction to the first one. This process, when carefully carried out, forms an ideal protection from electrolytic action. It is important to see that the twine is saturated before it is applied to the lead, as

many cable manufacturers serve the lead with dry twine and attempt to saturate it afterward, which process is almost certain to fail of its object.

The telephone companies, as I have already mentioned, have adopted a standard cable, called the "conference cable." This contains a sufficient number of pairs of small wires, usually 100 pairs, each pair being twisted on itself and the total number being made up into a loose strand. The insulation of the individual wire is a loosely applied strip of paper, dried by heat, but not filled in any way to prevent absorption of moisture. The lead sheath is forced by a continuous process over the strand of twisted pairs, and the ends of each length are sealed against the entrance of moisture by a filling of paraffine and a lead cap, which remains in position until the cable has to be jointed to the next length. Of course, a perforation of the lead would admit moisture to the cable, and, as the atmospheric moisture present on an ordinary damp day is quickly absorbed by the dry paper, very great care has to be taken to maintain the integrity of the lead sheath. The lead is not pure, but is alloyed with 2 or 3 per cent. of tin, which makes it considerably harder and less liable to stretch during the process of pulling in through the ducts. This alloy of lead and tin is almost universally used by American cablemakers. One maker prefers a pure lead with a surface coating of tin applied to it after the cable is otherwise complete. I don't find that this method is any better than the more common one.

The telegraph companies on their main lines have taken lately to using paper-insulated cables, not differing materially from those designed for telephone work, but most of the telegraph cables now underground are rubber insulated, the different wires being bunched under a tape and braid, and in all the later practice having the lead sheath over all. Telegraph cables for submarine work are always rubber insulated in American practice. The Atlantic cables and other long-distance cables are not made in American factories, and are, except when laid in tropical seas, insulated with gutta-percha. The usual finish of a submarine cable is a bedding of tanned jute, with an armoring of galvanized iron wires over all. Cables laid in water infested by the *teredo navalis* are sometimes protected by a copper or brass strip instead of the galvanized iron wires. Bunched cables for use by the American telegraph companies under rivers and estuaries have of late years been lead-sheathed over the bunch of rubber-insulated wires and before application of the jute bedding. The telephone companies avoid submarine cables as much as possible,

because of the bad effects of such cables on the talking capacity of the lines. When compelled to install them they usually follow telegraph practice.

Electric light practice to-day is about evenly divided between paper-insulated cables and rubber-insulated cables, both lead covered. The paper cable for electric light work differs altogether from that for telegraphic work, in that the paper is laid on closely and is saturated with a viscous compound. The paper is not laid on very tightly; the different layers are so disposed as to allow of a slight slip when the cable is bent, so preventing breaking of the paper, because it is necessary to avoid the presence of any cracks or crevice, extending from the copper of the conductor to the lead sheath. Such breaks in the continuity of the insulation are weak points, permitting the passage of high potential discharges, which would be withstood by the body of the insulation. The viscous filling has for its object the restoration of continuity by the slow movement of the filling into any crevice that may form. You will notice that in an electric light cable with paper insulation the paper is a true insulator, while in the telephone cable the paper simply serves to preserve the distance between the individual wires, and the air is the insulator. Rubber cables are preferred for high-tension work—5000 volts and upward—in our practice, although there are theoretical reasons in favor of paper. Only one of the numerous fibrous insulations with which the market was once filled now remains in the market. That is the Waring "ozite" filled cable, which has excellent mechanical qualities combined with a low cost. The other fibrous insulations have been displaced by paper. In choosing between rubber and paper insulation two considerations must be taken into account which are too frequently overlooked. The first is the possibility of the lead sheathing, on which the insulation of a paper-covered conductor finally depends, being destroyed by electrolysis. If electrolytic action is known to exist in the earth where the cable is to be laid, of course the lead should be protected in the first place, no matter what the insulation may be. But if the risk is only a remote one, liable to follow on future extensions of street railway lines, it is well to note that a rubber-insulated cable may continue in use long after the lead is perforated or destroyed. The other consideration, which some engineer or other of my acquaintance overlooks at least once a year, is that with high electro-motive force a definite space must be occupied by insulation all around the conductor to prevent what is called "punching-out"—that is to say, the passage of a

discharge from conductor to lead sheath, so that in many cases it is better to use a greater thickness of the cheaper insulation,—to wit, paper,—rather than a less thickness at equal cost of the more expensive material; and this, although the thin rubber wall will give a higher insulation, as tested in the usual way, than will the paper.

And in designing a cable system a thorough study should be made of the details of junctions and terminals. There are plenty of good cables to be had, and there are enough good jointers to make the splices in the cables, but there is a sad lack of details, such as switches, lamp connections, and service boxes, fit to stand the ordinary accidents of use at high electro-motive force.

In closing, it is necessary to say a few words about the systems of cables or conductors which do not permit of the withdrawing of the conductors, including in this the well-known solid systems, so-called, of Edison and of Ferranti. The best known of these systems in the United States is the Edison tube, wherein three solid copper rods are wrapped with cord so as to preserve their distance from one another, and placed in an iron pipe of sufficient size, the ends of the pipe being closed with hard rubber plugs and the interstices being filled up solid with an asphalt compound. The tubes are usually 20 feet long. The joints between these tubes are made by slightly flexible links, and the links and the ends of the tubes are protected by a turtle-shaped casting, which is finally filled with compound similar to that used in the tubes. There is more electric energy distributed over this style of conductor than over any other in use in the United States. The Edison tube system is to-day essentially the same as when it was introduced fourteen years ago, and in our own city several miles of tubing laid in 1886 are in use at the present moment, and have been continually in use since first laid. The special virtues of this method of arranging underground conductors are that its method of joining conductors permits the making of service connections at the junction of any two tubes, and that the tubes form a sufficient mechanical protection to the conductors against any of the usual disturbers of the subsoil. The only instances in this city in which these conductors have been injured by street excavations have been those where the work has produced a general settlement of the soil or a partial landslide, causing the joints (which are not designed to resist longitudinal strains) to open out. An example of this occurred in the alley south of the Hammond Building, when the excavation for the Union Trust Build-

ing was made. The soil of the alley, including part of the foundation of the Hammond Building, started forward into the excavation and the Edison tubes were torn apart.

The celebrated Ferranti tubes have been described so often and have been so limited in their use that they require no description from me. You will remember that they contain concentric conductors designed to carry current at a pressure of 10,000 volts; that the insulation is paper soaked with ozokerite, and that the joints are accurately turned tapers, male and female. The system was lacking in flexibility, and required an unusual order of skill and specially accurate machinery in making up the sections.

Some eight years ago another solid system of conductors was tried in several cities and under different names. The conductors were stranded copper cables without insulation, laid in a matrix of asphalt, the asphalt being confined by a wooden trough and covered with plank. The plan failed because of the softening of the asphalt, allowing the conductors to sag together, or in other instances, where the asphalt was sufficiently firm to resist sagging, through the opening of cracks allowing water from the soil to reach the conductors and cause short circuits. I may say that the finding of an asphalt insulating compound which will remain viscous at minimum temperature of the subsoil of the Northern American states and will still be firm enough at maximum temperature to prevent sagging of imbedded conductors is still an unsolved problem.

Finally, there have been laid underground a great many cables simply buried in the soil. This is a favorite practice in Europe, and the European cable manufacturers make cables armored with iron strip or with interlocking wire specially for this work. In this country such special cables are not regularly on the market, and the practice is not in favor, because of the continual tearing up of our streets for different purposes without proper supervision of the excavators. Lead-covered cables are laid occasionally in streets not likely to be disturbed, a bed of concrete or a creosoted plank being laid on top of the cable to give notice to the careless excavator. I am sorry to say that my own experience shows that neither concrete nor plank is effective. Our local wielders of the pick are not expected to think, and, being directed to open a trench, will work on faithfully through either concrete or plank, varying their straightforward digging only by an occasional "undercut" to the obstruction. At least two Polish citizens of Detroit have been educated during the last three months as to the inadvisability of undercutting small sec-

tions of concrete uncovered in trenches. One of the two knows now that he struck an electric light cable, and that the destruction of the point of his pick and the accompanying blaze were due to physical causes. The other man disappeared for the day, after his early morning experience of this kind, and at last accounts was still firmly convinced that there exists on Washington avenue, in front of St. Aloysius Church, a short and direct passage to the nether regions.

THE CONSTRUCTION OF THE HEMET DAM.

By James D. Schuyler, Member of the Technical Society of the Pacific Coast.

[Read before the Society, June 4, 1897.*]

California has, within her borders, a number of high masonry dams, possibly more than any other state in the Union, certainly more than any other Western state, and nearly all of these dams have been built within the past 10 years. The most prominent of these, named in the order of their height, are the San Mateo, Hemet, La Grange, Sweetwater, Folsom, and Bear Valley, all of which have been repeatedly described and discussed in engineering societies and in technical journals, as well as in the local periodicals, with the single exception of the Hemet Dam, which, though second in height, is apparently but little known, and is seldom mentioned in print except by the journals in the immediate locality, none of which have, however, given it complete or adequate illustration. This is due partly to the remoteness of the situation of the dam and the difficulty of reaching it, as well as to the modesty of the men who have constructed it and put it in service, without the flourish of trumpets which ordinarily announces the completion of a work of such magnitude, and which might be regarded as entirely justifiable in the present instance, where such a substantial addition to the wealth of a community has been made and so notable an object lesson given of the possibilities of water storage in the arid region.

The writer, having planned the structure and supervised its erection by occasional visits as consulting engineer, has been frequently invited to write an account of its construction for the enlightenment of the profession as to its details, and has recognized that it is a duty, which every engineer owes to his fellows, to make such a public record of the works constructed under his charge as will serve as a convenient reference for the future. Until recently, the immediate spur or incentive required for the preparation of such data was lacking, and the good intention was repeatedly put aside by more urgent demands upon the writer's time, but, having been employed to write a general paper on "Water Storage and Dam Construction in the Arid Region" for the Eighteenth Annual Report of the Hydrographic Division of the United States Geological Survey, shortly to be published, he revisited the dam, revised

*Manuscript received August 26, 1897.—Secretary, Ass'n of Eng. Socs.

his notes and drawings, and prepared an account of the work, from which the following is largely extracted by permission of the Chief Hydrographer, although rearranged and presented in somewhat different form.

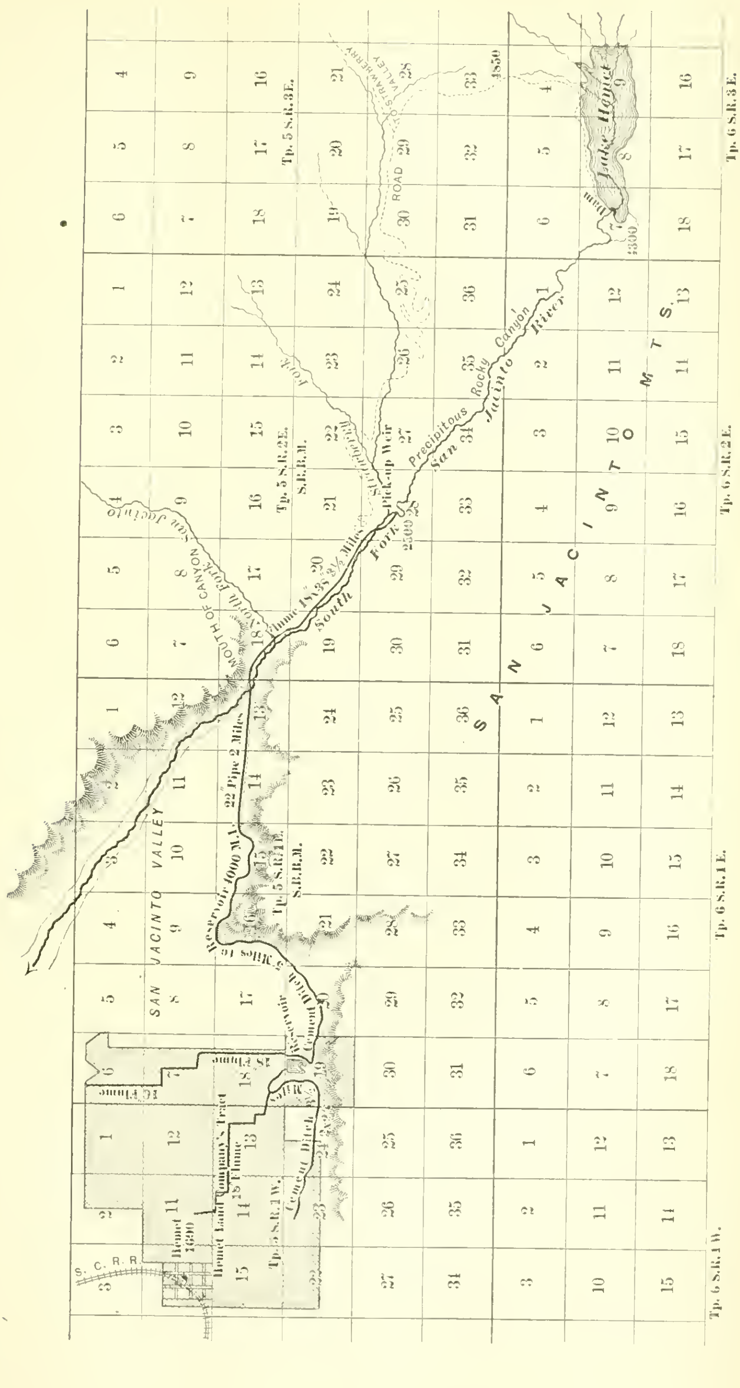
Hemet Valley, Fig. 1, whose outlet is closed by the dam of the same name, is an elevated mountain valley on the southern flank of San Jacinto Mountain, in Riverside County. The general altitude of the valley is about 4300 feet above sea-level. It is in the region of pine timber, which rather sparsely covers the valley and the mountain sides. It is a cold, frosty valley, unfit for agriculture and suitable only for grazing, for which it affords a coarse, hardy wire grass that cattle appear to thrive upon. It has never been occupied, except by a single family; subsisting on the stock-raising industry, which has not been interrupted by the construction of the dam, as by far the larger part of the valley is still above the high-water line of the reservoir.

Mt. San Jacinto and Grayback, which stand as sentinels, one on each side of the great gateway of San Gorgonio Pass, are two of the highest peaks in Southern California, and the former, 10,987 feet in altitude, is a trifle the higher of the two. The principal drainage of the peak is into the San Jacinto River, of which the South Fork, flowing through Hemet Valley, is the largest tributary. The area of watershed above the dam is variously estimated at from 65 to 150 square miles, although no surveys have been made to determine its boundaries with precision.

No reliable records have been kept of the precipitation, either at the dam or at any other points on the watershed, but it is quite evident from the topography that the precipitation at the dam would be the minimum of the entire shed.

The outlet from Hemet Valley is a narrow canyon in granite, through which the stream plunges for nine miles, making a total descent of about 2000 feet to its junction with Strawberry Fork, where is located the pick-up weir, which diverts water from the stream into a flume conveying it to the distributing system in the valley below. Hemet Dam is located at the head of this gorge at its narrowest point.

When the enterprise of constructing the dam was first considered, in 1886, plans were drawn for a structure which, had it been built, would have been more startling in dimensions than even the notorious Bear Valley Dam, as a uniform thickness of 4 feet from bottom to top was proposed, and the dam was to depend wholly upon the arch for its stability. It was to be curved up stream, with the shortest possible radius, and to be of cut stone



Lake Hemet
Dam
San Jacinto River
Precipitous Rocky Canyon
South Fork
North Fork San Jacinto
Pick-up Weir
Strawberry
Strawberry Valley Road
Mouth of Canyon
Flume
22" Pipe 2 Miles
Reservoir 4000 M.A.
Cement Ditch
Reservoir
San Jacinto Valley
San Jacinto Mts.
Hemet 1690
Hemet Land Company's Tract
18" Flume
16" Flume
S. C. R. R.
Tp. 5 S.R.3 E.
Tp. 5 S.R.2 E.
S.B.B.M.
Tp. 5 S.R.1 E.
Tp. 5 S.R.1 W.
Tp. 6 S.R.3 E.
Tp. 6 S.R.2 E.
Tp. 6 S.R.1 E.
Tp. 6 S.R.1 W.

FIG. I.

laid in cement. This structure was, however, not approved by the company, which shortly after changed hands, and, preliminary to the storage of water, it was decided by the new corporation, entitled the Lake Hemet Water Company, to first utilize the waters of the living stream to their full extent. For this purpose a 13-inch pipe was laid from the junction of the Strawberry and South Forks down the canyon 3¼ miles to its mouth, and thence out to the tract of 7000 acres of valley land acquired by the stockholders, over which the water was distributed in pipes.

The storage dam, though not actually begun, was in contemplation. Nevertheless, it was found that prospective land purchasers and home-seekers were skeptical of the sufficiency of the water supply with merely the normal stream flow of the South Fork as the only visible source, and, though the lands were otherwise all that could be desired, they were practically unsalable until the company began the actual building of the dam, and had finished it so far as to be able to store a considerable body of water behind it.

The site seemed specially suitable for a masonry structure because of the excellence of the bedrock foundation, the abundance of good granite and sand right at hand, and the narrowness of the canyon where it was to be located. A rock-fill dam was first considered among the possibilities; but, as the side walls of the canyon were no higher than the maximum height of dam proposed, most of the rock would have had to be hoisted and transported from quarries above and below, and the volume of material to be handled would have been so much greater than for a masonry dam that there was no apparent economy in favor of a rock-fill.

From the outset the projectors were determined to erect the best dam that men and money could build, and the writer was instructed to prepare plans suitable for the maximum height to which a dam could be built to advantage at this site. Considerable delay was occasioned by the necessity for constructing a wagon road up the mountain from the mouth of Strawberry Fork, and it required some time to induce the county supervisors to locate and build the road as a public highway. The company was anxious to have the road built directly into Hemet Valley by a route free from snowdrifts and on a maximum grade of 10 per cent., but other interests were strong enough to locate it on the slopes of a canyon intermediate between South Fork and Strawberry, where 18 per cent. grades were used, with many sharp turns, on a north slope where snow sometimes lies late in spring. This location is more convenient for the saw mills on Strawberry and North Fork,

but it compelled the construction of a branch road 5 miles long into Hemet, over a summit 500 feet higher than the reservoir. This road was finished in 1889, and in the summer of 1890 the plant for erection of the dam was assembled and excavation begun. The stripping of the foundations occupied several months, with the aid of a cableway for conveying and dumping the waste below the dam-site, and a considerable part of this time was required to excavate a deep "pot-hole" developed directly under the base of the dam, and within the exterior limits of the foundation. This hole was filled with bowlders and gravel tightly rammed in place, and might have been built over with perfect safety, but, as its depth was unknown at the outset, it was thoroughly cleaned out, although it required 500 yards of masonry to refill it.

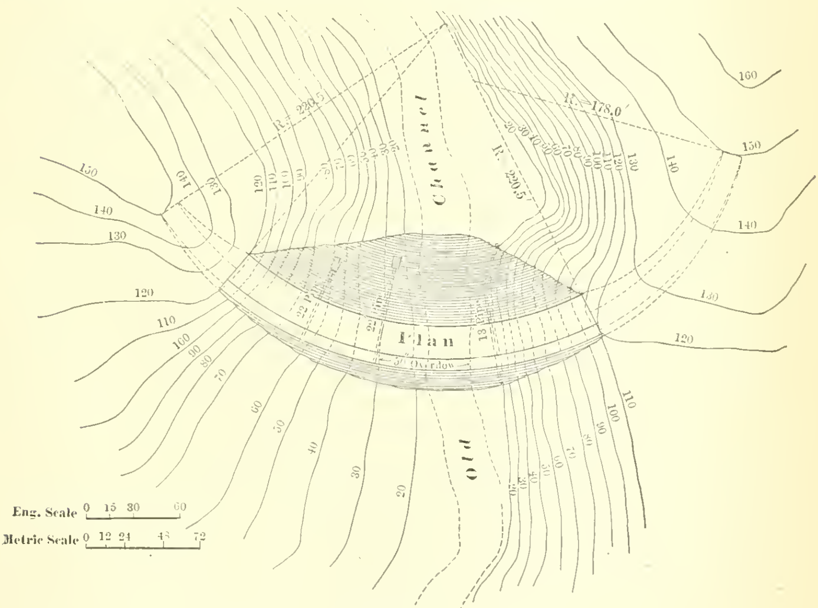


FIG. 2.

As a key or anchorage to receive the masonry of the dam, a center trench of irregular depth and width was cut in the rock on each side from bottom to top. While the work was progressing, the company's teams were busily engaged hauling up cement. The distance by the road from Hemet Station, on the Southern California Branch Railway, is 23 miles, and the total ascent to the summit is 2300 feet. The teams leaving the station every morning would go half-way up the mountain and be met there by teams leaving the dam at the same time, each team returning at

night to its starting point. The wagons were usually loaded with cordwood or lumber on the return trip. Owning their own teams and raising their own hay or grain, the company in this way reduced the cost of transportation of the cement to something less than $1 per barrel.

The erection of a sawmill to cut lumber for the boarding houses, stables, cement houses, shops, flumes, staging, and various other structures was the first essential in the erection of the plant, and the logs for this purpose were supplied by the necessary clearing of the reservoir basin. About 1,500,000 feet B. M. of lumber was cut in all, of which about two-thirds was consumed about the dam. This lumber cost $6 to $7 per 1000 feet. The tree-tops were cut up into cordwood.

PROFILE OF MASONRY DAM
(Looking Down Stream)

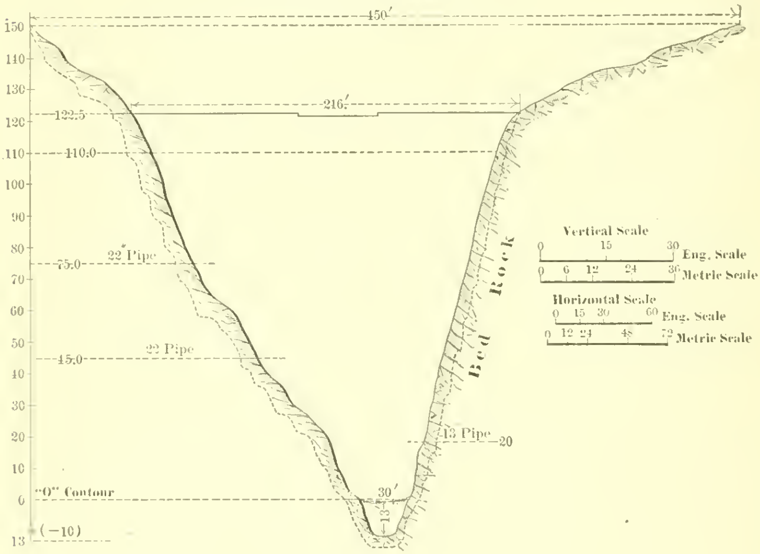
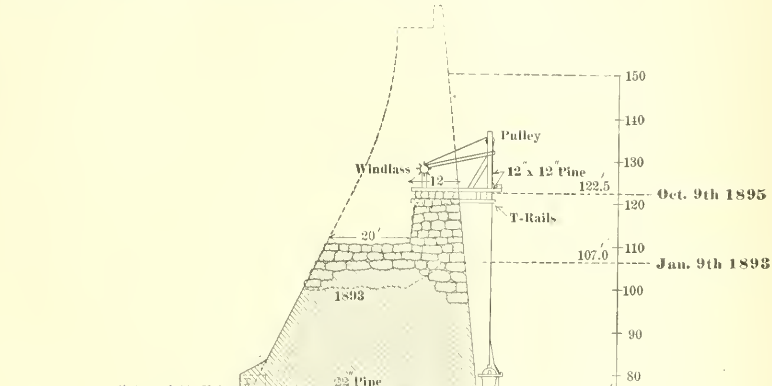


Fig. 3.

The actual erection of the dam began January 6, 1891, when the first stone was laid, and the work proceeded thenceforward without interruption until January 24, 1892, when severe weather and floods compelled a suspension of construction at the 45-foot contour, and four months elapsed before it could be resumed, when it was continued again without cessation until January 9, 1893, when the workmen were again driven off by a storm that filled the reservoir so rapidly that many of the buildings and tools were submerged, and the water ran over the top of the dam in a sheet several feet deep for a short time. By this time the dam had

reached the 107-foot level, at which the work remained until the fall of 1895, when construction was resumed and carried on to the present height of $122\frac{1}{2}$ feet above the creek bed, or $135\frac{1}{2}$ feet above the lowest foundations; and, on the 9th of October (the top of the wall having been finished off level, with the exception of 50 feet in the center, which was left one foot lower than the remainder as an overflow channel), the machinery was all removed and the work was considered practically finished, for some years to come at least, although it has been projected to go to the ultimate height of 160 feet above the stream bed.



SECTION OF MASONRY DAM

FIG. 4.

The dam, Figs. 2, 3, and 4, is 100 feet thick at base, and has a batter of 1 in 10 on the water face, and 5 in 10 on the lower side. Its present crest is 260 feet long, while the length at bottom is but 40 feet. It was carried up with full profile to the height of 110 feet above base, at which height it is 30 feet in thickness.

Here an offset of 18 feet was made, and the wall reduced to 12 feet thickness. At the top it is finished to a thickness of 10 feet.

The top of the dam is now level with the lowest notch of a gap in the ridge to the south, which has been filled with a short embankment of earth 6 feet in height. Any increase in height of the dam will necessitate the construction of an earthen barrier of sufficient height to close this gap. At the 150-foot level the waste water could be spilled over a broad, bed-rock sill between the dam and the gap referred to.

The dam is arched up stream with a radius of 225.4 feet at the upper face on 150 feet contour, and is built of uncoursed, rough granite rubble, laid in Portland cement concrete throughout the body of the work, the faces for 3 or 4 feet in thickness being laid in cement mortar, with large stones specially selected for true faces and beds. None of the stones were cut, although the facing stones were roughly scabbled. Before leaving the quarry all the stones were washed clean with jets of water from rubber hose under considerable pressure. This washing was usually done after the stones were chained and before they were hoisted above reach.

The total cubic contents of the dam are 31,105 cubic yards, requiring approximately 20,000 barrels of cement, which cost about $5 per barrel delivered on the ground.

The stone was all quarried within 400 feet of the dam, on both sides of the canyon both above and below, and was hoisted and conveyed to the wall by two cableways, each cable being about 800 feet long and 1½ inches in diameter. These were placed up and down the stream, crossing the dam nearly at right angles with the long chord of the arch, but diverging from each other and anchored to convenient trees on each side of the gorge below. At the upper end both cables were attached to points on the right bank. Their position was seldom changed, except to lift them higher up into the tree-tops and to erect "A" frames on top of the masonry to support them when the wall had reached such a height as to require it. Loads of 10 tons could be hoisted and handled with ease, and such a load could be hoisted 150 feet vertically and conveyed 200 to 300 feet horizontally in from 40 to 60 seconds. Two derricks, one at each end, were placed on top of the dam in such position as to receive the loads directly from the cable and swing them into position at any part of the wall desired. These derricks were operated with water power obtained from a 3-foot Pelton wheel, propelled under a head of 75 feet by about 80 miners' inches of water brought from the stream in a flume 1½

miles long. This flume passed under the concrete mixer, where the penstock was located, whence a 13-inch pipe carried the water to the wheel placed below the dam. This pipe was afterward imbedded in the masonry of the dam at about the 20-foot contour, and it is so arranged that it can be used as the lowest outlet from the reservoir.

The carriages traveling on the cable, and the devices for sustaining the hoisting fall as the load moved back and forth, were designed by the author and a very ingenious and capable superintendent of the work, Mr. E. L. Mayberry, himself a large stockholder in the company and a contractor and builder of varied and extensive experience.

The sand used was clean and sharp, and was accumulated constantly, as it was rolled along the bottom of the flowing stream, by a temporary log-dam reservoir, whence it was periodically discharged into a sandbox below by opening sluice gates. From the sandbox it was conveyed to the mixing platform by an endless wire rope carried with triangular buckets of sheet-iron, holding about a quart each, and placed at intervals of 20 feet along the double wire rope, which passed over drums in the sandbox below and on the platform above. The wire ropes were about 12 inches apart. The hoist was about 125 feet, and the horizontal distance over which it was conveyed was 350 to 400 feet. This device was operated by the same engine which propelled the rock crusher and concrete mixer. It was almost automatic in its operation and gave very little trouble, delivering the sand thoroughly washed in the quantity desired, and emptying it into bins, where the exact charge for a mixing was accurately gauged.

The concrete used to embed the blocks of stone was mixed in the proportion of one of cement, three of sand, and six of broken stone, crushed to pass through a 2½-inch ring.

The stones were placed not less than 6 inches apart, and the spaces between them filled with smaller stone, all well rammed into place with iron rammers. A bedding of concrete, 3 inches or more in thickness, was made for each of the large stones, and this was carefully rammed under the edges all around before other stones were placed against it. This use of cement enabled unskilled laborers to perform much of the work, and stone masons were employed only on the facings. The latter were paid $3 to $3.50 per day. Laborers received $1.75 per day.

The mixing of both mortar and concrete was done by machinery, which is undoubtedly superior to hand mixing in the quality of the output. The grinding and pounding of the particles

of aggregates together in the revolving mixing machine appears to result in the more complete coating of the sand and rock with cement than is possible to secure by hand mixing, however carefully the latter may be performed. That this intimate mechanical action is of positive value in increasing the strength of cement or concrete is apparently demonstrated by the remarkable tests obtained from the new "silica cement," now being introduced throughout Europe and the Eastern states, which consists merely of sand and cement ground together.

The mixing platform was located on the right bank, about 300 feet above the dam, which was as near as it was possible to find the necessary room at the most convenient level, which was at the 80-foot contour. From this point a trestle was built along the face of the cliff to the dam, and on this a double track was placed, over which iron cars, pushed by hand, conveyed the concrete and mortar to the line of the dam. The cars were dumped into chutes which conveyed the material to the level of the work, whence it was shoveled again into wheelbarrows and delivered where required. When the dam had reached the level of the top of the trestle, an elevator was built at the mixer and another track was carried out on top of the cliff, at about the level at which the work was completed.

Information as to the cost of the masonry or of any other portion of the work is withheld by the company, for reasons affecting its dealings with the County Assessor on the one hand and with the Board of Supervisors, having power to fix water rates, on the other. Under favorable conditions, some of the masonry was put in for as low as $4 per cubic yard.

The outlets of the dam, Fig. 5, consist of two 22-inch lap-welded iron pipes, 11-32 inch thick, placed at the 45 and 75-foot levels, respectively, in lengths of 20 feet, fastened together with flanged and bolted joints. At the up-stream ends of the pipes are cast-iron elbows turning upward and flaring outward to 30 inches diameter, and closed by hemispherical valves or covers, each manipulated by a wire rope passing over a pulley and windlass on a frame secured to iron "T" rails embedded in the masonry at the top of the dam. These covers are ordinarily removed, and replaced by cylindrical fish-screens, 3 feet diameter, 12 feet high, standing vertically on the valve seat of the pipe from which water is being drawn. The main control is had by gate valves set at the lower line of the dam, from which the water falls freely to the rocks below in a fine spray, collecting in a pool a short distance

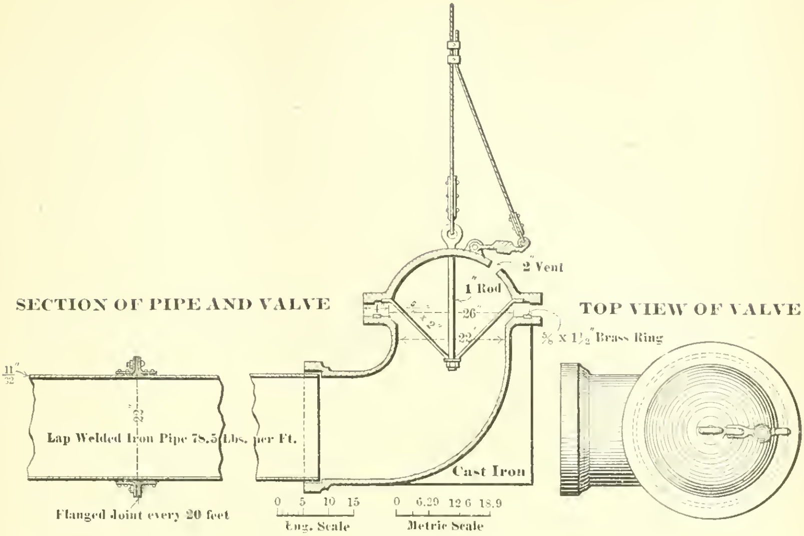

SECTION OF PIPE AND VALVE
TOP VIEW OF VALVE
2" Vent
1" Rod
26"
22"
⅝ x 1½" Brass Ring
Lap Welded Iron Pipe 78.5 Lbs. per Ft.
Cast Iron
Flanged Joint every 20 feet
0 5 10 15
Eng. Scale
0 6.29 12 6 18.9
Metric Scale

FIG. 5.

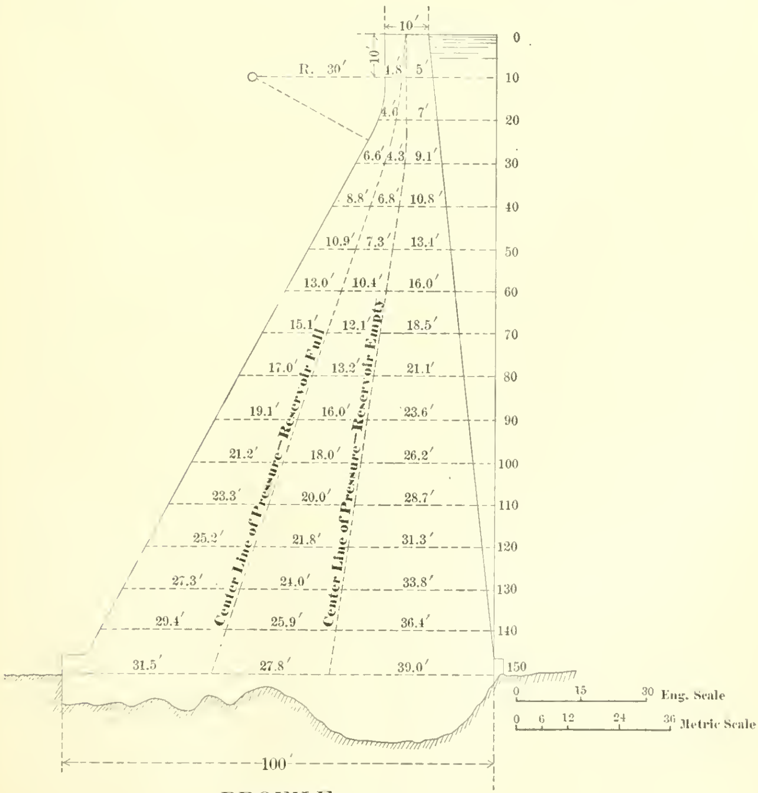

10′
R. 30′
Center Line of Pressure—Reservoir Full
Center Line of Pressure—Reservoir Empty
100′
0 15 30 Eng. Scale
0 6 12 24 36 Metric Scale
PROFILE

FIG. 6.

from the dam, and passing over a weir for measurement before beginning the plunge down the canyon.

Considerable leakage occurred through the masonry prior to the fall of 1894, when the water was drawn down and the entire face of the wall was carefully repointed. This resulted in materially lessening the leaks, so that they now are reduced to a mere sweating in patches here and there over the lower face, and the total leakage in the spring of 1897, with gauge at 101.5 feet, measured but 1200 cubic feet per day.

The profile of the dam, Fig. 6, is of the gravity type, in which the line of pressure, with full reservoir, falls just outside the inner third of the base at all points. The writer has always favored the arched form for all masonry dams as a measure of stability or as a factor of safety against all possible contingencies, even though their gravity be sufficient to render them entirely stable to resist maximum water pressure. In this connection it will be of interest to quote the arguments in favor of curved reservoir walls advanced by Professor Forchheimer, of Aix-la-Chapelle, Germany, in discussing a series of papers on "Impounding Reservoirs," recently read before the Institution of Civil Engineers.* Referring to a masonry dam eighty-two feet high, plastered and rendered over with two coats of asphalt, built by Professor Intze in Remscheid, Westphalia, he says:

> A backwards-and-forwards movement, amounting to 1 1-16 inches, occurred during the filling and emptying of the reservoir, and the movement due to temperature was almost as great as this. The latter was due less to the temperature of the air than to direct solar radiation. The crest of this dam was 460 feet long, and was arched with a radius of 420 feet. One side was exposed to the sun longer than the other, and the more exposed part moved to and fro 7/8 inch in the course of the year, while the other part moved only 1/8 inch, the crest expanding 1-9000 of its length, or 5/8 inch. In arched dams such movements do no harm; but in straight dams these phenomena are objectionable. As dams are usually built during the warmer seasons of the year, the masonry has a tendency to contract in the colder weather. In a curved dam this can take place by movement of the structure without cracking, but not in a straight dam. * * * If the temperature was lowered 10° Cent. (18° Fahr.), and it was not free to contract, lesion amounting to between 140 and 280 pounds per square inch was set up, which is greater than the mortar would stand. * * * That a straight or almost straight wall incurred considerable danger of fracture is shown by practical experience. The dams of Habra, Grands-Cheurfas, and Sig, in Algiers, had broken, and in that of Hamiz a tear had occurred during the first filling. The Habra dam broke in December and the Grands-Cheurfas and Sig dams gave way in the month of February. The Beetaloo dam in Australia had also developed a crack

*Proceedings Inst. C. E., vol. cxv, p. 156.

⅛ inch wide in the middle of winter without any apparent cause. The Mouche dam, Haute Marne, a structure 1346 feet long and about 100 feet high, exhibited clearly the dangers attending straight dams. In the winter of 1890–91, when the temperature varied between 10° and 20° Cent. (50° to 68° Fahr.), and the water surface was 10 feet 8 inches below the normal level, seven vertical cracks appeared in the dam, situated at uniform distances of about 160 feet apart. They were widest at the top, and died out about 37 feet below the normal water level. Their aggregate breadth was 2⅞ inches. The cracks gradually closed as the temperature rose, and by the end of February, 1891, four of them had completely vanished, whilst the others had perceptibly contracted.

For the information of the profession, the writer will add that there are no visible cracks whatever in the Hemet dam, nor, indeed, in any other curved masonry dam which he has ever visited.

THE RESERVOIR.

The capacity of the reservoir, as it is completed at present, is 10,500 acre-feet (3,430,000,000 gallons). By carrying the dam to the 150-foot contour this capacity could be increased to nearly two and a half times, while the 160-foot level would give a capacity of nearly 35,000 acre-feet. The following is a table of capacity at different levels:

Height above base of dam.	Surface area, acres.	Capacity of reservoir, acre-feet.	Remarks.
40	2	33	
45	2.3	73	Lowest outlet at 45 ft.
50	3	113	
60	29	332	
70	62	773	
80	103	1,603	
90	133	2,787	
100	187	4,391	
110	252	6,598	
120	328	9,512	
122.5	365	10,500	Top of dam.
130	486	13,590	
140	601	19,077	
150	738	25,836	

THE CONDUIT.

As before stated, water released from the dam flows down the bed of the South Fork canyon, Fig. 1, 9 miles to the pick-up weir just above the mouth of Strawberry Fork, where it is diverted into a flume. This weir is a low timber structure of no special importance. Great difficulty was experienced, before the building of the dam and for a year or so after, in disposing of the sand flow down the canyon, and an ingenious mechanical device was

arranged by Mr. Mayberry for automatically settling and hoisting out the sand from the settling tank by the power of the flowing water passing over an overshot wheel at a sandhouse a little way below the dam. This has all become obsolete now, however, as the stream has been comparatively free from sand since the building of the dam, which evidently came chiefly from Hemet valley. From this it may be argued that the reservoir is destined to become rapidly filled with sedimentary deposit. The progress of this filling is as yet, however, imperceptible, and, as the reservoir is capable of impounding the normal annual run-off, the ratio of sand flow to water is too small to make alarming inroads upon the reservoir capacity.

The main conduit, below the pick-up weir just mentioned, is 3.24 miles in length to the mouth of the canyon, where it connects with a 22-inch pipe 2 miles long, which, in turn, discharges into an open ditch 5 miles in length, lined with masonry and plastered with cement, which delivers water to a distributing reservoir at the highest corner of the irrigated tract. The flume in the canyon is 38 inches wide inside by 18 inches deep, and has an average grade of about 140 feet per mile. The longitudinal joints of the bottom boards are battened underneath and calked inside with oakum, and triangular strips are nailed in the corners. The interior of the flume is coated with asphalt and the outside with lime whitewash, which is an excellent preservative of wood and adds greatly to the appearance of such a structure. The lining lumber is $1\frac{1}{2}$ inches in thickness. A portion of the flume is built of redwood and the remainder of mountain pine cut from the reservoir basin, which, though knotted and inclined to warp, has nevertheless made a remarkably tight and serviceable flume. One of the peculiarities of this structure is that after completion the lumber appeared to expand lengthwise when wet, so much as to amount to about one foot in the first mile, so that the posts of the low trestles supporting it were thrown off their feet, and it became necessary to put in "expansion joints."

The main ditch leading to the distributing reservoir is lined with granite cobbles from the river bed, of about 10 inches maximum diameter, laid in lime and cement mortar in equal parts, and plastered with Portland cement and sand. The ditch is 2.75 feet wide on bottom, 7 feet at top, 2.75 feet deep, and has a capacity of 60 second-feet. A portion of it was rendered over with asphalt which was unskillfully applied, and, though serviceable for some years, has been removed and replaced with cement plaster. Ditch linings of asphalt require to be homogeneous to be successful,

apparently, as it refuses to adhere to masonry where there is any moisture in the latter.

THE DISTRIBUTING SYSTEM

through the tract consists of smaller cemented ditches, flumes, and pipes, of which there are 30 miles altogether, covering the entire area. The slope of the land is about 40 feet per mile from east to west, which facilitates the distribution of water in conduits of small size.

THE DISTRIBUTING RESERVOIR.

The dam of the distributing reservoir is of earth, 300 feet long, 14 feet high, 8 feet wide on top. In construction, a trench 10 feet wide, 9 feet deep, was excavated under the center line, and in the middle of this trench a tight board fence was built, with boards placed horizontally, from near the bottom of the trench to the top of the dam, to prevent the burrowing of ground squirrels and gophers, a function which it effectually performs. The trench was refilled with puddled earth on each side of the fence, and the puddle was also brought up to the top of the embankment. The reservoir covers about 20 acres in area, and has a capacity of about 90 acre-feet; and from it is distributed the supply to the lateral ditches and flumes covering the tract irrigated. The domestic supply pipe to the town of Hemet is also arranged to discharge any surplus water into the reservoir, as well as to draw from the reservoir in case of necessity.

THE LANDS IRRIGATED.

The area actually irrigated from this system was 1092 acres in 1896, and it is increasing year by year. The planting is chiefly in deciduous fruits, and is divided into 72 tracts, of which the usual size is from 10 to 20 acres. The rates charged for water are $2 per acre per annum, with an additional charge for domestic supply of $1 per month for each service or tract during the non-irrigating season, which is stipulated in the water-right contracts to be from November 10 to April 10. In the town of Hemet there are 55 taps paying a uniform rate of $1.50 each per month.

The apportionment of water by the water-right contracts given with the deeds to the land is at the rate of "one eighth of one miners inch of perpetual flow from April 15 to November 15 of each year for each acre, which is equivalent to 39,312 cubic feet or 0.9 acre-feet. The rate of $2 per acre would therefore be equal to a charge of 5 cents per 1000 cubic feet, or $\frac{2}{3}$ cent per 1000 gal-

lons. No attempt being now made to restrict the consumer to this precise quantity, it is as yet uncertain as to whether this quantity could be made to suffice for the thorough irrigation of the crops which will there be planted. The quantity used during 1896, as measured over the weir at the base of the dam, was 111,600,000 cubic feet, an average of 102,000 cubic feet per acre irrigated, or a mean of 2.34 feet (28 inches) in depth over the entire surface. The computation does not take into consideration the possible loss by leakage and evaporation in the conduits and the distributing reservoir, nor the possible loss or gain in the flow down the 9 miles of canyon below the dam. The measuring weir at the dam is also imperfect, and the velocity of approach, which was unknown and neglected in the computation, would rather tend to increase the total volume stated, or offset the losses mentioned. The figures given indicate in a general way, however, that unless the irrigators are wasting water extravagantly while free to use what they like, the apportionment to which they are legally entitled under their water-right contracts is inadequate. The reservoir, when filled annually, may be regarded as capable of irrigating, or furnishing water for irrigating, about one acre of land for every 2 acre-feet of reservoir capacity, and therefore, as the present capacity of the reservoir is 10,500 acre-feet, it will supply 5250 acres with abundant water.

The freshets of winter, and the run-off from melting snow in the spring, are counted on quite certainly to fill the reservoir before the irrigation season begins, and ordinarily the summer showers add material reinforcement to the supply.

The normal summer flow of the stream, which is ordinarily about 4 second-feet, is considered as more than adequate to offset the loss by evaporation on the surface of the lake for the entire year, and therefore, taking one year with another, the supply available may be considered sufficient for the entire tract of 7000 acres. Further experience, both with the catchment from the watershed and with the duty of water in irrigation, is necessary, however, before definite estimates of this sort can be made with safety.

The soil of the tract is a fine, mellow, sandy loam, of great depth and fertility, seemingly unchanged in character as far down as 100 feet; and when the water table of this region shall have been raised to within 10 or 15 feet of the surface, after years of continuous irrigation, the duty of water upon the land will doubtless be greatly increased.

DISCUSSION.

MR. GRUNSKY.—This dam is somewhat similar to the dam constructed by two irrigation districts at La Grange, on the Tuolumne river. The latter has a total height, as I recollect, of 128 feet. It is rather remarkable in this, that the water flows over the top of the dam. It is really a large diverting weir. The water drops from high-water level about 100 feet to low-water level. The amount of masonry in this structure is 39,000 cubic yards, which is a little in excess of the amount in the Hemet dam.

These dams, of unusual dimensions and unusual character, are becoming more numerous from year to year in California, and this state is taking the lead to a large extent in the matter of the construction of peculiar types of dams, as is quite well known to all the members of the society.

There is one feature dwelt upon by Mr. Schuyler that indicates in what way a water supply system for irrigation can be made profitable. It is the combination ownership of land and water. When parties not interested in the sale and distribution of the water own the lands to be irrigated, the demand for water grows slowly. To illustrate how a combination ownership of land and water may be a financial success, an example from Kings river may be cited. About 1882 the promoters of an irrigation enterprise, known as the "76" canal, commenced operations by securing water rights, and at the same time purchasing about 40,000 acres of land scattered through the district commanded by the proposed canal. The price paid for the land ranged from $5 to $10 an acre.

They then expended about $200,000 in constructing their works. The main canal was made 100 feet wide on the bottom and about 8 feet deep. They sold the land at a price sufficiently high to cover the cost of canal construction and leave a handsome margin besides. Their operations were so successful that their properties, which had by 1886 cost them about $300,000 in the aggregate, were then estimated to be worth $800,000.

It is a fact too often overlooked that where irrigation ditches are constructed simply for the sale of water the people are very slow to take the water, and the revenue from its sale increases slowly. It is rare to find an irrigation work not combined with land sales, which has been profitable from the outset.

MR. WAGONER.—I would like to have Mr. Grunsky explain more in detail the arrangement for taking the water out of the river, especially as to the head works.

MR. GRUNSKY.—The Kings river is a peculiar stream. It

leaves the foothills over a very broad bed of coarse cobbles, some large enough to be called bowlders. On account of bars in the river at various stages there are subsiduary channels, and the water is very easily turned from one into the other. By a temporary barrier a larger flow of water may be diverted into one of these channels, from which a diversion is easily accomplished. In this particular case the southernmost channel of the river was selected. At its head the cobbles were thrown out until the channel was sufficiently enlarged to cause a large portion of Kings river to flow in it. Wherever an obstruction was met with that would deflect the water from the southernmost channel, the one leading the water off was closed, so as to hold the southernmost channel full of water. From this channel a cut about 9 feet deep is made into the south side bench land, and in this cut the head-gate is placed. It is 100 feet from bank to bank. The head-gate or regulator serves as a bridge, weighted on top, and is divided into 20 openings. The openings are between posts, and gates move vertically between these posts. In four of these gates there are revolving shutters, something like a butterfly valve. Its width up and down stream is 30 feet. The bridge is just wide enough for convenient travel.

Mr. Wagoner.—What kind of lumber was used?

Mr. Grunsky.—Redwood was used for the lower part of the structure, and some pine was used above. The simplest types of structures are used to divert the water from the canal. Very light weirs of timber are placed across the canal. Generally the weir is carried into the banks for a short distance and then bulkheads built, to which wings are connected. The space between these bulkheads is floored, sheeting being used on the upper and lower line of the floor, and is divided into about 4-foot spaces by means of inclined posts. These posts are provided with grooves, and inch boards slide in these grooves. The weir boards are moved by hand, and can be removed singly. Water flowing over the top of them drops upon the floor of the structure below. They are supported by inclined shoring from below. A plank is generally laid across the top of the weir posts in such a way as to give convenient access to any part of the structure. This serves as a footpath. The same type of structure answers for all lateral canals to reduce fall and to aid in diverting water.

Mr. Henny.—In connection with this enterprise, Mr. Grunsky has referred to the fact that the promoters first bought the land, which he considers to some extent the secret of financial success. It seems to me that there may have been still another

reason for the financial success of the Kern County enterprise, and that is in the fact that no large amount of money was necessary to build storage works; all that had to be done was simply to divert the water from the river. This was in 1882. Presumably at that time all the river water had not been appropriated. The question may be asked whether it has become necessary for the company in question, in case they did take water that had been appropriated, to settle with the people who had a prior right to it. Such settlement, of course, would involve additional expense. It appears to me that in prospective irrigating enterprises the element of time is often improperly left out of account. The cost of the works is figured, and the annual revenue expected from the territory covered; but usually promoters fail to allow for the number of years that must pass before all this territory is settled, a factor which I think has much to do with the financial failure of many such enterprises in this state.

Referring to the expansion of timber, I find that lengthwise swelling of the wood, as shown by the author, is not confined to redwood. On an average, redwood does not swell lengthwise much more than other woods. The amount of lengthwise shrinkage is very uneven, however, varying in the experiments that I have made from 0.07 to 0.39 per cent., and averaging 0.141 per cent.

I might state that in 1887 I was planning in Arizona a flume that was to be constructed of mountain pine, which I presume is identical with the pine of the San Jacinto mountains; and I was told by those who had experience in the longitudinal shrinking of that lumber that it was greater than in any other timber they had seen. We made some experiments by sinking a plank under water and leaving it for a month and then letting it dry out. I do not remember just what it was, but it was about two and a half times greater than the amount given in the tables for longitudinal shrinkage. That wood is generally softer than the California species and more liable to be knotty; in fact, it is difficult to get sound, first-class timber from it. We found that a block that was thoroughly waterlogged, having been submerged for a month, and then allowed to dry for 2 days, would take fire from a match and would be entirely consumed.

Mr. Grunsky.—Mr. Henny suggests that in irrigation works there may be a good deal of expense in buying up water rights. I will state that nearly all the canals in the great central valley of the state are engaged in more or less litigation. It is very difficult indeed to determine just what the rights of a canal owner are.

The law prescribes that when a person desires to take a water right he may post a notice. The notice is generally written in a very indefinite way, and very often refers to the spot where the notice is posted, without designating where that spot is; and when a man wants to take 300 inches of water he writes 30,000 inches, so as to cover enough by the notice, and that notice is then filed in the office of the County Recorder. When he gets ready to construct his ditch, although he may have described in his notice a canal 30 feet wide, he is not ready to build any such a canal, and builds a ditch only 2 or 3 feet wide on the bottom. He uses that for perhaps 10 years before he is ready to enlarge. There is no record made of such facts. They live only in the memory of the people in the neighborhood, unless the ditch owner gets into litigation and the matter is brought up in court. This condition of things in our state has brought on almost interminable litigation as to water rights, entirely aside from those caused by the riparian doctrine, according to which the owner of the land upon the banks of a stream is supposed to have a right to have the water flow past his land undiminished in quantity and unimpaired in purity. The law needs to be revised in regard to the acquisition of water rights. There should be one central place where all records are made. No one should have a claim to water until he actually takes it and puts it to beneficial use. The notice should fix the time, if he complies with additional requirements, to which the taking of water is to be referred, and his ditch capacity and the amount of water taken should be determined by competent state authority by actual measurement of the ditch he constructs. There should be a state department in which all records relating to water appropriation are kept, and a system of ditch measurements should be instituted so that records would be concentrated at one point, and not scattered through all the counties. Individual ditch owners and all municipal and other corporations that are interested in water would then know just exactly what their rights are. If a good permanent department of this character could be instituted it would certainly be of great advantage to the state.

Professor Soule.—The old method of the Spaniards and Mexicans has come in contact with the method of riparian ownership brought over from England, and there is a rivalry of those two systems in our state, the state having been originally settled by the Spaniards and subsequently by the English. I have had occasion to look into these matters, and have exchanged views on it, and I do not think that we exactly know where we are on this question. I quite agree with Mr. Grunsky's suggestions for improvement.

Mr. Henny.—Mr. Grunsky's plea for a central place of record cannot be too strongly endorsed, but I think he has only partly stated the legal troubles. He has not mentioned the question of underground water. In the southern part of the state there are many companies dependent upon that source for supply. The law provides that percolating water belongs to the owner of the soil, and he can do with it as he pleases, and anybody who is damaged because of its use has no redress. On the other hand, the law speaks of "underground well defined streams," which are subject to riparian ownership and appropriation, the same as surface streams. These terms are not specific enough. It is sometimes hard to tell when a stream is well defined. The State Engineer's office could be of considerable service in the way of giving advice on questions of this kind, and such advice would have due weight in the courts and would establish presumptive evidence.

THE NEW ROAD LAW OF MONTANA.

By M. S. Parker, Member of the Montana Society of Engineers.

[Read before the Society, March 30, 1897.*]

The law recently enacted† making county surveyors general superintendents of all roads in their respective counties is a step in the direction of progress, and I sincerely trust that the surveyors throughout the state will make an effort to prove the wisdom of this progressive measure. They will be annoyed by the existence of that relic of antiquity, the present road-tax law. Rome, however, was not built in a day, and the perfection of road laws is not to be accomplished in a single legislative session. We must take the laws as we find them, and make the best use of the opportunities afforded thereby.

One of the worst features of road laws is that they permit tax-payers to pay their road-tax in labor instead of in money. This law was inherited by the United States from England, where it was introduced in the eleventh century,—a relic of the feudal system brought over from the continent of Europe. For a long time this system was continued in England, and during all the time it was in force the roads were in very much the same condition as they are now in the United States. A good many years ago the law was abolished, and, as a consequence, few countries can to-day boast of better roads than England. The United States is lagging along behind the mother country, though we claim to have progressed more rapidly than England by reason of our freedom from old-established customs that retard progress there.

This custom of working out road-taxes, which has long been abandoned in England, is adhered to tenaciously in most parts of the United States, and, as a consequence, our roads are as much behind the times as is the old custom referred to. Farmers are frequently censured for bad work done upon our highways by them. The fault is not theirs, but of the system under which they work, and that system would produce practically the same results under any other class of men. The road supervisor warns out the men, and, in a general way, tells them what tools to bring. The

*Manuscript received September 8, 1897.—Secretary, Ass'n of Eng. Socs.

†Road and County Surveyors' Laws of Montana are published in full in the Journal of the present year. See Proceedings of Montana Society of Engineers, page 9 of the present number, and vol. xviii, No. 3, March, 1897, page 44.

men come or not, as suits their convenience. The supervisor, however experienced he may be in road building, cannot accomplish much with an inexperienced and very uncertain crew to work with. The main object of the worker, in most cases, is to get in the day and satisfy the tax. The road overseer or a contractor, with a well-organized and thoroughly equipped crew under him, is able to accomplish work better and infinitely cheaper than the disorganized crews called out at times to work out road-taxes. Work can be laid out for such organized crews by the engineer of roads, and it can be done as it should be, from the beginning. Under this system, in course of years, the country would be netted with good roads instead of the poor roads to be found all over the United States as a result of the old feudal law that has remained on the statute books of most of our states since the beginning of our country.

The road-tax in Montana is $3 per capita per year for each able-bodied man over 21 and under 45 years of age, or one day's labor on the public roads in lieu of such payment. The right to pay said tax either in labor or in money is optional with the taxpayer. Of those who elect to work out the tax, and so inform the county assessor, probably not one-half ever report for a day's work on the roads. If the road-tax were reduced one-half and made payable in cash only, the result on the roads would soon be realized and appreciated by the taxpayers at large. First-class roads have never been built anywhere under the old law, and there is no reason to expect that they will be in the future.

The Legislature of Montana has recently passed a law placing the roads under the supervision of county surveyors. This is a step toward securing good roads; but the Legislature has handicapped the work by a road-tax law that permits the working out of road-taxes. Had the labor-option clause been omitted, and had the tax been made $2 instead of $3 per capita, the law would be in accord with wisdom and common-sense, the outgrowth of universal experience. The greatest obstacle in the way of good public road building is this law permitting the working out of road-taxes.

WORKING ROAD-TAX HANDS.

This, in my opinion, is the first and only problem. The plan that will be adopted in Cascade county for working out road-tax is to appoint a manager in each township where necessary, whose duties will be to supervise the work of those who elect to work out their road-tax. General instructions will be issued to these managers as to how roads should be built, and they will conform,

as nearly as possible, to these instructions. It will be the duty of these managers to see that every man in his district who elects to work out his tax does so. As the manager cannot work with less than five men, except under certain provisions, he will, if desirous of working, see that his crew of five is complete. No money will be spent under the direction of such a manager without being ordered by the county surveyor. The main object is to get done the work that is due, relying on the manager to put it where it will do the most good. Farmers working near their homes will do something for their own roads. They cannot be taken far from home to work. A man and team will be taken as equivalent to two days' work, as by the law required. Managers must depend upon this means to obtain teams for their work. These methods will be used to keep roads passable throughout the county. All such managers will give bond to the county surveyor in the sum of $500 for faithful performance of his duty and as custodian of property.

DISTRICTS.

The county will be divided into four districts, to simplify accounts, and each district will have a manager, under whose direction all permanent road building will be done. Each of these managers will have an organized force under him, and will work under the personal direction of the county surveyor. These outfits will be moved from place to place, living in camps.

CASCADE COUNTY POLICY.

It will be the policy of the county surveyor to keep the organized crews on the main roads leading through the county,—the main arteries of travel,—and to systematically build permanent roads, as far as the means at hand will permit, macadamizing where necessary. If this system is carried out for a few years, there will be good main roads throughout the county. Lateral roads will be left to the last, and work done upon them only to the extent of keeping them passable.

GRADES.

As for grades, this is largely a matter of topography. Grades should be kept down to the limit of the territory traversed. They should be the best that the ground affords. Grades should never be sacrificed to property rights. If a road is worth building, it should be located where it belongs. The keeping of a record of grades, as required by law, is practicable, but it will take time to

accomplish it, as nothing has ever been done in the matter of grades heretofore. It will be the policy in Cascade county to begin a system of grades from Great Falls, the county seat, using a Government bench mark as the datum for all levels. Levels will be run as soon as practicable on the main roads leading through the county, and bench marks established at intervals of a mile. Permanent roads will be built to established grades. I do not apprehend any present necessity of carrying the matter further than the maintenance of proper grades on roads to be built in the future, and in changing old roads, where practicable, to reasonable grades.

Cascade county has about 1000 miles of road, and to establish grades for all this mileage would be folly at present. It will require years to get many of the little-traveled lateral roads up to an established grade.

CULVERTS AND DRAINS.

These will depend upon circumstances. At present no standard is adopted.

GRADING MACHINES.

These machines are well adapted for road grading in certain localities, particularly in a prairie country. In some parts of Montana they can be used to advantage, in connection with a road-roller, to pack the newly graded road. The road-scraper is a useful machine, particularly in leveling earth roads that have been badly cut up and left rough after the spring rains.

A road-grading machine, together with a heavy road-roller, will be recommended for use in Cascade county in the near future.

I am firmly of the opinion that the change in road supervision will result in good to the state. The duties of the county surveyor will be arduous and will require good executive ability on his part. It remains with him to prove the wisdom of the change in management of county roads. The compensation is entirely inadequate for the ability required to properly administer the duties of the office. A competent engineer can hardly afford to devote the time necessary to conduct the affairs of the office. This will be a serious obstacle in the way of procuring the best talent. It is to be hoped, however, that the county surveyors of Montana will do all in their power, during the ensuing two years, to make the law, of which our state is the pioneer, so successful in its operation that two years hence it may be so improved as to become a model for our sister states to accept.

DISCUSSION.

Mr. Kirkendall.—If a man has neither money nor property, and if he is invited to work on the road and refuses to do so, is there any law to make him work or confine him in jail.

Mr. Penwell.—I believe there is.

Mr. Thorpe.—It appears to me that allowing the furnishing of a substitute is one of the objectionable features in the new law, and one of the matters we should endeavor to have repealed at the next meeting of the Legislature. I think every man should either do the work himself or pay the road-tax in money. At any rate, if the substitute is not fully able to do the work, I do not believe we are compelled to take him.

Mr. Keerl.—As there appears to be some doubt as to the operations of the new law, I move that the Attorney-General be called upon for a comprehensive opinion on this law.

Mr. Wardwell.—Mr. Parker speaks of establishing grades for roads. It appears to me that each county surveyor should decide for himself the proper grade to use, as the conditions are so frequently changed in this western country. A road, at first unimportant, may, in a short time, become very important, owing to the opening up of new mines or other improvements. A road over which loads of ore, weighing from four to six tons, are to be hauled will not admit of heavy grades.

Mr. Wade.—A chain will hold only what its weakest link will hold. We can draw over a road only what can be drawn over its worst place, and consequently that one place will rule the traffic that goes over the road. It appears to me we should pay particular attention to grades. The need of proper grades is particularly apparent to freighters. Recently a freighter, in urging me to change a grade on a certain hill, said: "Why, Mr. Wade, every time we load for Helena we really load for that hill." With a proper grade at that particular point, 25 per cent. could be added to every load that passes over that route.

THE CONSULTING ENGINEER IN MUNICIPAL AFFAIRS.

By Wm. H. Searles, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, September 14, 1897.*]

In the administration of the material affairs of a great and growing city no one will deny the importance and necessity of an engineering department. So many features of civic growth relate to the physical and material improvement of the territory occupied by the city, and these so evidently demand, for their proper management, the study and superintendence of men skilled in technical details that the employment of civil engineers becomes a matter of course.

In the village stage of city growth this feature of the public service may properly consist of a chief engineer and a small corps of assistants. The chief engages personally in all the engineering work done, whether in field work or office, with the assistance of a few young men. But, as the city increases in size and the amount of work grows in proportion, this simple method of administration becomes impossible. The duties of the engineer office are subdivided again and again; at first perhaps only into a field and an office corps; then the field corps is subdivided by districts of the city or by distinct classes of duty, or both; the office corps is similarly divided and draftsmen of different degrees of skill are assigned to the work suited to their several abilities; but all employes, whether in field or in office, are still under the immediate orders of the chief. Such a system grows up by the gradually increasing demands upon the department, and without any special design; and it works well enough for a series of years, but at length it becomes unwieldy by its very expansion. The chief finds himself overtaxed by the multiplicity of items brought to his notice, while the assistants are embarrassed and delayed for lack of prompt and definite orders.

To obviate the difficulties growing out of this state of affairs it is customary to reorganize the engineer department by the establishment of a number of bureaus, each devoted to a particular class of work exclusively, and each presided over by an engineer who makes that class of work his specialty. Such a head of a bureau directs largely the details of work under him, subject, however, to

*Manuscript received September 16, 1897.—Secretary, Ass'n of Eng. Socs.

the orders of the chief engineer, to whom he reports from time to time, and upon whom the responsibility for the character of the work accomplished finally rests. This form of organization is excellent in design, and, if properly carried out, usually secures the execution of the details of routine work with satisfactory dispatch.

The organization is similar to that adopted by railroad companies and private corporations doing business on a large scale. It so subdivides the labor that no part is necessarily neglected, and, while requiring ability in some one line on the part of the head of each bureau, it does not require of him ability and experience outside of the duties of that bureau. These subordinate heads of bureaus may therefore be, and they generally are, young men of good parts, but possibly of an experience limited to the scope of the bureau over which each presides.

A large part of the duty of a city engineer is found to be routine in its nature, of which repairs form a prominent feature. The work to be laid out is governed by precedent and patterned after work previously performed. A pavement worn out is to be relaid to the same grade, or a sewer too small is to be replaced by a larger, or a bridge superannuated is to be rebuilt. The work having been authorized by Council, is ordered by the chief, and is executed under the direction of the bureau head and his assistants. This seems so simple in statement that one feels confidence in the smooth and satisfactory execution of the work demanded, and such is usually the case, as far as routine work is concerned. Nevertheless, the multiplication of items in the ever-widening territory of a great city, and the increasing demand for repairs added to the demand for extensions and additions, serves to burden each bureau, and most of all the chief engineer, with a weight of duty and responsibility unrealized by any except the incumbent himself. It is only by severe application to duty, and often by overwork beyond the stipulated office hours, that the business of the office is kept abreast of the city's demand.

This general description fits quite well the present condition of the engineer office of the city of Cleveland. The city has long outgrown its village conditions and even those of a minor town. It not only aspires to metropolitan proportions, but finds itself compelled to assume them by the increasing demands upon it of commerce, of manufactures, and of the thronging population which these great industries attract and support. Not only increasing numbers, but also increasing wealth, make it the plain duty of the city government to provide clean and comfortable thoroughfares, wholesome conditions as to sewerage, a pure and abundant supply

of water, safe, permanent, and commodious bridges and viaducts, and beautiful and health-giving parks and boulevards for the use and comfort of the citizens.

Not less is it the duty of the city government to afford all possible facilities to the commerce that already seeks this port, and to commerce that would come here if opportunity and space were afforded for it. Here is a herculean task, yet one upon the proper execution of which the future prosperity of the city largely depends. It involves the expenditure of millions of dollars, while the proper and wise investment of this money is largely an engineering question. These great improvements which coming generations will be called upon to pay for should be designed and executed with reference not only to our needs of to-day, but to the wants of the century to come. Works of a temporary and flimsy construction, such as were excusable in a young community fifty years ago, are not to be tolerated for a moment. The improvements must not only be well designed, but must be permanent in character, so as to avoid as far as possible, for the future, the expense of either alterations or repairs.

The necessity for these improvements is conceded; the legislation precedent to the raising of the funds has already been accomplished. The question most important in this connection now is, on whom is to devolve the responsibility of devising and maturing the engineering plans upon which the expenditures are to be made. Ought this burden to be laid on the present engineer office of the city as now constituted? Most clearly not. It would be a gross injustice to the officials themselves to pile upon them these added duties when they are already taxed to the limit of endurance by their current official duty. Nor could we hope for the best results in plans for new work to which only hasty and partial attention could be paid in the intervals snatched from other pressing engagements.

Neither would it be wise to intrust these vast material interests to the care of another subordinate bureau of the engineer office, to be called perhaps the Bureau of Design. It would not be wise, because a bureau is necessarily limited in scope and authority; its work is performed largely by assistant engineers, without a broad experience, and must come up for revision and correction to the chief engineer probably a number of times before final approval. Were it simply a matter of detail it might be left to such a bureau to perfect, but we have here a problem of the broadest nature, involving untold interests in the future, and one that is to be solved only by the close and devoted study of well-trained and experienced

engineers, of liberal ideas, and free from other and distracting duties.

The several great problems now before the city, of sewage disposal, of harbor improvement, and of park adornment, though separate in themselves, have the common feature that they deserve to be treated comprehensively, and so carried out that every part shall be consistent with the rest. No detail should be decided upon except as it will fit properly into its place in the general design for all time to come.

In order to secure the end in view and guarantee that the funds to be expended in a grand municipal improvement shall be rationally and economically expended, the city should call into being a co-ordinate branch of the engineer office charged with the sole duty of considering the general problem in all its aspects, commercial, financial, and technical; to be presided over by an engineer of national reputation, who should be required to give his whole attention to the questions in hand. This officer should be furnished with offices and assistants quite distinct, so as not to interfere in the least with the routine duties of the present organization. After properly gathering all necessary data, he should be allowed sufficient time properly to weigh all the facts and to evolve a design that will never need to be repented of. Upon the completion and adoption of these designs they should finally be turned over to the chief engineer for execution, with the advice and friendly co-operation of the designer, who may perhaps be designated by the title of consulting engineer.

By such a differentiation of duty great advantages to the city are to be secured. Let all new work originate in the office of the consulting engineer. The plans and specifications will then be prepared on a scientific basis, and in accordance with the best practice of the world. The consulting engineer in the privacy of his office, and free from the demands upon his time so constantly made by the public upon the chief engineer, can work out a comprehensive and consistent scheme of improvement sufficient to meet all reasonable demands. Drawing upon his own resources as an expert, and in friendly communication with the best engineering talent the world affords, he will produce results on which his own professional reputation will be staked, free from all political influences or petty personal favoritism in their design, and thus give to the city a body of improvements of which it may justly be proud for all time to come.

The consulting engineer should have the privilege of selecting his own assistants, in order that his ideas may be thoroughly car-

ried out and expressed by them. For all information on record he would call on the chief engineer. For any new surveys or examinations he may call on the chief engineer, who will order them made by regular assistants, or, if the examinations were special in their nature and likely to interfere too seriously with the regular work, a special corps might be temporarily organized for the purpose. The plans and specifications would be matured directly under the eye of the consulting engineer, and would exhibit a harmony of design and completeness of detail impossible to realize under less favorable circumstances.

On the other hand, the chief engineer, being relieved from the responsibility of originating new and important designs, can give his undivided attention to the work of construction. By a well organized corps of assistants he may so direct the laying out of the work and the inspection of materials, and so control the quality of workmanship that every part of the scheme shall be thoroughly and consistently executed to his own professional credit and to the enduring advantage of the city he serves.

This last and most important division of expert service,—that of consulting engineer,—is not in the least suggestive of antagonism or jealousy in the engineer office. The division is a natural one, and founded on scientific principles. It is in accord with the best engineering practice and with the functions of the human mind. The duties of the two co-ordinate branches are quite distinct, yet perfectly complimentary to each other. The duties of the two require for their perfect performance different orders of mind. A man well adapted to the one is presumably not so well adapted to the other. By the division of duty into two classes the city obtains superior service in each. It is not a division into theoretical and practical engineering, as some might ill-advisedly infer. The designing engineer must be as practical as the constructing engineer; but he must also be so familiar with the immutable laws of nature, the strength of materials, the results of many tests, the use of many intricate formulæ necessary in the proportioning of parts, and with all that vast mass of information which goes to constitute the equipment of an expert engineer; that one cannot reasonably be expected to excel in this line who is charged with directing a large force of men, and seeing that their several duties are properly performed from day to day on works already under construction.

This division of expert labor is not without precedent. It is common on the more important railroads and wherever the highest grade of engineering work is to be accomplished. There can be

no good reason why the city of Cleveland should not avail itself of the same method. The great public interests at stake demand it; by no other means are the best results to be secured. It is in line with the only true economy. The cost of the additional office is not worth considering in comparison. As well might a steamboat company dispense with a pilot to save his salary.

The present is a most opportune time for making the innovation here, on the eve of enterprises heretofore unparalleled in this city, and requiring expenditures of money beyond all previous estimates. Naturally, in undertaking a new voyage the first step is to provide a pilot.

It may be objected to this general proposition that the end to be gained may be reached by the employment of a temporary commission of experts, to be called in as the occasion may demand from to time.

To this objection it may be replied that,

First. The very fact that such commissions have been several times created by this city proves conclusively that the necessity for a consulting engineer in some shape was felt to exist at those times, and is likely to occur again.

Second. The men serving on those commissions have been called from distant cities with minds preoccupied with their home duties, with little or no prior familiarity with our local conditions, depending upon such facts and figures as may be furnished them on arrival, and upon such hasty personal inspection as a one day's drive over the ground will enable them to make.

In contrast with these conditions, consider the advantage to the city in the services of a consulting engineer permanently engaged, giving his whole interest and attention to the problems here to be met, familiar with the records of the city, and able to make further examinations and surveys at any time that such seem to be necessary.

Third. The report of a foreign commission carries no authority with it. It is true the members have been selected for their high reputation and well-known ability; their report is presumably formulated upon their combined judgment, with all the care that the time at their disposal will permit. It may be a monument of wisdom, and yet after it is received and filed no one appears to feel under any obligations to follow its direction.

On the other hand, if a similar report were issued from a municipal office under the authority of a high municipal officer, such as a consulting engineer should be, the report would carry weight, and those who were opposed to it would have to show

cause why it should not be adopted. Its author would be present to answer objections and to defend its measures if necessary.

Fourth. The expense connected with such commissions is necessarily great, yet their advice is confined quite strictly to the questions laid before them. A very few such commissions in the course of a year would cost an amount equal to a salary at which any member of the commission could be secured to serve the city in a permanent capacity, with the inestimable advantage of his constant personal presence and study of the engineering questions that will continually arise.

Fifth. The report of a commission has no necessary relation to those which have preceded it. They may therefore be inconsistent, if not contradictory, and it might be impossible for the city to follow them all literally.

On the contrary, the reports and designs issuing from the permanent office of the city's consulting engineer would exhibit a uniformity of purpose and plan, and would be consistent one with another, so that all could be reasonably carried out with the greatest advantage to the city.

As the city solicitor, or director of law, is frequently called upon for opinions as to the constitutionality or legality of certain measures proposed, so would the consulting engineer be called on to decide upon the practicability and economy of various schemes proposed; his adverse opinion,—based on a knowledge of nature's laws, which never can be violated with impunity,—serving to save the city many thousands of dollars which might otherwise be squandered in useless experiment.

Under a consulting engineer we should see much less of the now common practice of signing local remonstrances against proposed improvements, partly because such improvements would have been so wisely designed as to be open to very little criticism, and partly because, as part of a general scheme, no alteration in plans could be made without doing, at some other point, greater actual harm than that locally complained of.

It thus appears from many points of view that the function of consulting engineer would form a desirable and important feature in the public service. It is an office called for by considerations of public health and commercial prosperity; it would greatly facilitate the wise direction of public works, and would promote the economical expenditure of the public funds; it would assist the city government to make municipal improvements on sound and broad principles, insuring the greatest good to the greatest number, both in the present and succeeding generations of men. The proposi-

tion to create and maintain such an office should receive the cordial support of every broad-minded and public-spirited citizen, and is likely to be opposed only by those whose sole care it is to conserve petty personal or partisan interests.

The city of Cleveland would have profited greatly in the past from the services of a permanent consulting engineer; for the future his services will be found to be absolutely indispensable.

AVERAGE LIFE OF CROSS-TIES IN STEAM RAILROADS IN COLORADO.

By William Ashton, Member Denver Society of Civil Engineers.

[Read before the Society, January 14, 1896.*]

In renewing cross-ties they are usually gone over but once a year. The portion of track gone over for renewal of ties in the spring is seldom gone over again later in the season, but all ties left in the track at the time the renewals are made are supposed to be good for at least one more year's service.

Most of the ties now used in Colorado are of native pine and spruce. A few oak ties are brought into the state for use under very heavy traffic and on sharp curves, but, by the aid of tie-plates, closer spacing, and better rail-braces, aided by the wider rail-base and stiffer rail, we are now enabled to use pine and spruce native ties at points where their use would have been considered unsafe a few years ago.

When I began railroading it was thought proper to use soft wood ties only on tangents. In looking over some of my old papers I find that in Kansas and Nebraska, as late as 1881, my instructions, when in charge of track-laying on branch lines that were never expected to carry heavy traffic, were to the effect that soft wood ties, such as cedar, cypress, or pine, might be laid in tangents, on 1° curves every third tie must be oak; on 2° curves at least one-half the cross-ties must be oak, and on 3° curves all ties must be of oak. As we had no curves sharper than 3°, I can only guess at what we should have done had we struck an 18° curve. In those days, however, we used only 2640 ties to the mile and 50 to 52-pound rail. Now we frequently use 3200 ties per mile, and seldom less than 2900, while very little new rail is being rolled of a less weight than 65 pounds per yard, if intended for standard gauge track; while the rail rolled in the year 1895 for standard gauge will probably average at least 70 pounds per yard in the West and heavier in the East. While many more ties are used now for a mile of track than a few years ago, I fail to notice a reduction in the size or quality of the different classes. I think the oak ties we get now are fully as good as those we got fifteen years ago, and the same may be said of ties of other woods.

In my opinion, ties are now better cared for than they were,

*Manuscript received September 13, 1897.—Secretary, Ass'n of Eng. Socs.

and last longer than they did, a few years ago. The increased strength of the rail distributes the weight over a greater number of ties, and much more evenly, than when lighter rails were in use. As a result the ties get less individual punishment under the traffic, even though it has materially increased in weight per lineal foot of train, and although our tracks are subjected to much greater loads and speeds than they were a few years ago. I believe the track has fully kept pace with the increased weight and speed of trains, and is fully as safe as the poorer track was at the slower speeds. I do not intend by this to assert that I believe that our track is entirely satisfactory and good enough for the present traffic, but, while I am fully aware of the unsatisfactory results we get from the present method of track construction and maintenance, of the very primitive manner of fastening the rail to the ties, the weak points at the rail joints, in spite of the almost numberless joint splices and other devices being brought out, yet I feel full confidence in asserting that the track of to-day is as safe and satisfactory, except perhaps from a financial standpoint, as it was a few years ago, when our trains weighed half as much and ran at half the speed; and this safety has been maintained and kept in unison with the increased requirements with the same inferior substructure of wooden ties, supplemented by a few new inventions for increasing their efficiency and possibly somewhat increasing their durability.

Tie-plates are undoubtedly a means of increasing the life of soft wood ties, especially of ties that have naturally quite a long life in the soil, and which were destroyed largely by the cutting and crushing action of the rail where it rested upon the tie. On such ties the tie-plate also aids in holding the track to gauge and tends to prevent the spreading of the rails on curves or elsewhere.

Under ordinary circumstances, my experience on the lines in Colorado, has been that ties of Colorado pine, balsam, and white spruce will last in track $3\frac{1}{2}$ to 4 years under ordinarily heavy traffic. Under light traffic, on a well tied track, they will probably average 4 years. On our main line we usually take out about half of these ties after 3 years' service and the balance the fourth year. On sidings and spurs, where they had very little traffic over them, where no renewals of such ties would be made until the fourth year; yet if, during the third year, this track had been subjected to a fast heavy train, many of the ties would have been found broken and possibly some of them crushed. We have alkali lands where the ties seem to burn out; that is, there seems to be something in this soil that destroys the fiber of the wood, causing it to become worthless in respect both to its tensile strength and to its resist-

ance to crushing. The ties enumerated above often last only two years in this soil.

Yellow spruce, as found in Colorado, lasts in the track about 4 years.

Red spruce is the best of Colorado tie timber. It is a strong, firm wood, holds spike well, and lasts usually 5 years, and in some cases will average 5½ and even 6 years.

Colorado timber, cut at a high elevation, lasts, in some cases, fully one year less than that cut lower down, especially if laid at a considerably less elevation than where it grew. I cannot fully account for this, but it may be in part explained by the fact that the timber grown at a lower elevation has less moisture, grows slower; and is therefore tougher and closer grained.

I think the cost of metallic ties is one of the principal reasons why they are not used more extensively at the present day. To this may be added the lack of uniformity in opinion as to the best form and the absence of any good practical metallic tie. It seems to me that the metallic tie has not yet been taken up seriously enough to make it a success. Trials have been made of different forms of metallic ties, but they usually proved expensive, and at that the railway company would give it up and go back to the wooden tie. If it were not for the old wooden tie to fall back on, we would have metallic ties of a pattern and efficiency that would give little cause for complaint, but I do not look for the general adoption of this kind of a tie until they can be not only furnished at a cost which will compete with wooden ties, durability considered, and until they are made of such form as to admit of their being put in track without having a machinist for a section foreman. I fail to find any reason for expecting that the adoption of metallic ties will materially reduce the cost of track maintenance, except in the matter of renewals of ties, and even with metallic ties, we shall have to keep practically the same kind of track forces as we do now, with perhaps one or two less men on a section during the summer. We will still have to depend on common labor. Therefore we want a metallic tie that can be handled by this class of labor, or a tie that will call for so little attention that we can afford to hire special skilled labor to handle and look after them. We shall require the same amount of lining, ballasting, track raising, widening of banks, cutting of weeds, draining of cuts and other miscellaneous work of this character as heretofore. This work will have to be done by cheap labor, and this labor is what will be called on to put in metallic ties.

ATLANTIC COPPER MINE, HOUGHTON COUNTY, MICHIGAN.

By Theodore Dengler.

[Read before the Denver Society of Civil Engineers, December 8, 1896.*]

In the copper mines of Lake Superior much labor is sometimes expended, as in the Atlantic mine, upon a rock containing low values, but giving a fair earning on the investment.

With one or two exceptions the present producing mines have been in active operation from 25 to 30 years, from which you will correctly infer that they are deep mines, the shafts ranging from 1200 to 5000 feet on an incline. Among the more notable mines are the Calumet and Hecla, Tamarack, Quincy, Osceola, Franklin, Atlantic, Kearsarge and Wolverine, in the order of their output the Calumet and Hecla being the largest.

The mineral beds consist of amygdaloidal traps and conglomerates impregnated locally with metallic copper. The dip of these beds varies from 56° at the Atlantic, the most southerly mine, to 37½° at the Calumet and Hecla mine, 15 miles northeast, and to 26° at the Central mine, 18 miles further northeast.

In the amygdaloidal beds, the copper, as a rule, occurs in an irregular manner, in the form of chutes and pockets requiring much dead work in finding and opening out the rich ground. The Atlantic lode is a single exception. Here, the copper being evenly distributed, little dead work is required and the whole bed is stoped. In conglomerates, the copper is generally very evenly distributed.

The region has been a study for geologists as much as that of Cripple Creek, if not more. Dr. Wadsworth, the former geologist of Michigan, now president of the Michigan Mining School, in speaking of the Calumet and Hecla mine, says: "This famous mine has as a lode an old sea beach conglomerate which is underlaid by a lava flow as well as overlaid by one, and the copper has been chemically deposited within this conglomerate by the percolating waters long subsequent to its formation, and after it was deeply buried under successive lava flows. Although many speak of the Calumet 'vein,' neither that mine nor any other in the Portage Lake division is worked upon a vein or upon anything that in the slightest degree approaches a vein in its character. All are bed mines."

*Manuscript received September 13, 1897.—Secretary, Ass'n of Eng. Socs.

This gives you the why and wherefore in a nutshell, and is the prevailing idea in the minds of most scientific men who have had occasion to be on the lookout in the district.

In the foregoing statement the term "bed mines" does not include some of the mines at the northeast end of the region, which have been closed down. They were worked on "true" fissure veins lying across the beds which I have mentioned at about 90° and have become impoverished with depth. The veins produced chiefly mass copper, the masses varying in weight from a pound to several tons, with some mill rock. The largest mass I have heard of was found in the Central mine. Its total weight was given out as about 600 tons, and no little labor was required to reduce it to shape for handling. I am told that 2 years were required to remove it in pieces small enough to go into a reverberatory furnace. A piece of this mass was on exhibition at the Chicago World's Fair in 1893. At present we hear of but few very large masses in bed mines, and, when they do appear in the working mines, they sometimes cost more than their worth to extract them. The only practical means for reducing masses is with cold chisel and hammer. Prices as high as $10 per square foot of cut have been paid for this work to experienced men.

The largest producer of native copper is undoubtedly the Calumet and Hecla mine, which produces a minimum of 3000 tons of refined copper a month. The Anaconda mine in Montana exceeds this output, but its product is from copper ores containing a high percentage of copper.

The Calumet has the largest machinery and the deepest shafts of any mine in the world. It is working upon a conglomerate carrying about 3½ per cent. of copper. There are twelve shafts, the deepest being a little over 5000 feet on the incline, while the latest undertaking was to put down a six-compartment shaft measuring 20 x 15.5 feet over all, 4900 feet vertically, through dead ground, from which cross-cuts have been made to the lode. This shaft cut the conglomerate at 3300 feet.

The total horse power of the boilers at the mine and stamp mill, commercial standard, is 22,422.

The aggregate horse power which can be developed by the engines belonging to the company is 40,000. A notable feature to be observed at the mine and mill is that the hoisting engines and pumps are arranged in pairs. Should an accident happen to the engine in use, the duplicate engine can immediately be put into operation.

The company employs some 3456 men.

About a mile northwest, on the hanging wall side of the Calumet and Hecla conglomerate, the Tamarack Mining Company is sinking a shaft 7 x27 feet, which is expected to cut the same conglomerate at a vertical depth of 4600 feet. The lode at this mine is very wide, about 22 feet, twice as thick as the conglomerate usually is. The company has four shafts in operation, with depths of 3234 feet, 4200 feet, and 4393 feet, respectively. About 1426 men and boys are employed at the mine and mill.

At most of the mines the men are lowered to the work by means of skips or a man-engine, but at the Quincy mine there is an attractive feature in the rapid handling of men. Formerly they were sent in and out of the mine on the old-fashioned time-consuming man-engine; they are now lowered and raised in a man-car, and the entire force underground, about 400 souls, can be got in or out of the mine in thirty minutes. The man-car bears a close resemblance to a flight of stairs, the under side of which is provided with wheels that rest upon the shaft track. There are banisters on this section of stairs to prevent the men from being crowded over the sides. The men take their seats on the steps and are gently lowered into the earth a distance of 4000 feet on the incline. Thirty men are carried at a load. The change from the man-cars to the skips is made at each shaft in less than 2 minutes. Two 5-ton cranes are placed in each shaft house, one on each side of the skip road, and with these the man-cars are lifted off, and the skips substituted in the time given.

While the Calumet and Hecla and other mines carry the distinction of being big producers, no little attention has been directed to the Atlantic mine by reason of the excellent results achieved in its operation.

This mine is situated about 3 miles southwest from the town of Houghton, and 8 miles inland from Lake Superior. It is working upon an amygdaloidal trap extending N. 52° E., dip 56°, and with an average thickness of about 10 feet. The rock yields about 0.73 per cent of refined copper or 14.6 pounds per ton of rock treated. At 10.52 cents a pound (which the management realized 1895) this amounts to $1.5352 for the average value in every ton of rock treated. This is the smallest percentage of copper per ton of rock that is being worked in the district with profit, other mines having all the way from 1.5 to 3.5 per cent.

With this small value in the rock, the company managed, in 1895, to earn a gross profit of $110,600. The ground broken and the product for the year were as follows:

Extract from Mine Report for 1895:

Ground broken in openings and stopes	20,037 fathoms
Rock stamped	331,058 tons
Product of mineral	6,239,000 pounds
Which gave a product of refined copper	4,832,497 "

The expenses were divided as follows:

Cost per ton of mining, selecting and breaking, and all surface expenses, including taxes	$0.7525
Cost per ton of transportation 8 miles to stamp mill	.0408
" " " " stamping and separating	.2220
" " " " freight, smelting and marketing product, including New York office expenses	.1881
Total cost per ton of running expenses	$1.2034
Gross earning per ton of rock treated	$0.3318

In 1894 the yield was 14.06 pounds of copper per ton of rock. Receiving a gross value of $1.3376 for the copper in a ton of rock the mine managed to earn $48,763.

The company employs about 450 (?) men and boys at the mine and mill. The management strives, above all things, to keep the skips in the four shafts hoisting rock; and, barring an occasional accident, the skips are in continuous travel from 7 A.M. to 5 P.M, and again from 7 P.M. to 5 A.M., stopping a few minutes at 12 o'clock for oiling up. The interval of two hours between shifts in the morning and evening are devoted to the hoisting and lowering of men, stulls and lagging. Engines, cars and skips are oiled and greased, fires are raked and everything is put in order for the next shift.

A miner or trammer, failing to be on hand to go down or up in this interval, will find it necessary to climb a few thousand feet of ladders or else risk his life in jumping for the skip while it is in motion. Though the latter is often done, the offender is liable to be discharged if discovered in the act by an official.

The hoisting plant at each shaft is in charge of an engineer and a boy, the latter attends to the firing and feeding of the boiler at the command of the engineer, the boiler being in full view of the engineer.

Most of the trammers are Findlanders. The miners are mostly Cornish. Boys, generally the sons of miners and laborers employed about the mine, are used where possible in engine houses and the stamp mill at $18 to $20 per month.

Miners' wages average about $52 to $55, and trammers receive from $38 to $45 per month.

The district, being in communication with the East both by rail and water, has the advantage of low freight rates. Especially is this the case with coal. Vessels which carry iron ore and lumber from points on Lake Superior to Cleveland, will take on a cargo of coal at Cleveland, charging a small rate rather than return light with no profit. By this means good Ohio soft coal is laid down in Houghton at about $2.25 per ton.

The Atlantic also receives good sound maple cord wood along its railroad.

The mine and mill consumed $77,314.75 in coal and wood during the year 1895.

There are four shafts, the deepest being 2150 feet on the incline. The hoisting engine at each shaft is assisted in its work by a "dummy" of cast iron which travels up and down on a small track alongside the skip road. Being of about the same weight as the rock in the skip, 3000 pounds, it affords a partial balance to the engine.

The mine is opened out laterally about 4800 feet. All mining is done on contract. The prices paid range from $5 to $7 per foot drifting, $7 per fathom for stopes and $20 for shaft sinking. The net cost to the company is probably less than this, as these are prices upon which miners have always based their bids when dynamite was more expensive than it is now, and the company furnishes the explosive at the former price, reserving the profit due to the variation and present lower price of the dynamite.

The company furnishes Little Giant Rand drill machines, of which there are 28 in operation, and makes all repairs to the machines.

Compressed air is delivered to within 50 feet of the working place by iron pipes. All other items, such as bits, powder, air-hose, etc., are charged to the miner. Bits are sharpened by the company's blacksmith gratis to the miner. The ground broken in the mine is about six months in advance of the tramming, and would run the mill for that length of time should anything cause the mine to close down.

Tramming is done on company account, a trammer receiving from $38 to $45 per month for 10-hour shifts.

The water in the mine is removed by a Cornish pump from No. 3 shaft towards which all the water in the mine is drained.

The rock is hoisted in skips weighing 4500 pounds, with a capacity of 3000 pounds, traveling at an average speed of 750 feet per minute.

The four shaft-houses are connected by a trestle, over which

the rock is transferred by rope haulage to the rock or crusher-house at one end of the property. Herein all the rock is crushed in Blake rock breakers, to pieces about the size of one's hand and smaller. Any small masses which appear are picked out and sent direct to the refinery. The crushed rock falls into bins, from which it is transported by rail to the stamp mill a distance of 8 miles. At the mill, the rock is further reduced in size, in 18 inch steam stamps, having a capacity of 250 tons each day. The shoe on these stamps weigh, when new, 700 pounds, and lasts about 18 days, its weight having been reduced by that time to 250 pounds or less. The stamped material is washed through 2 screens, with meshes or slots $\frac{1}{8}$ inch by $\frac{1}{4}$ inch, placed at either end of the mortar. Thence the material is passed over a hydraulic separator, which separates it into particles of five different sizes, four of which pass through Collum jigging machines, of which there are fifty-six to each stamp head. The fifth or smallest particles, called slimes, are run over revolving slime tables and thence to keeves. The resulting product of the stamp mill averages 76.46 per cent. of pure copper. This is put into barrels having a capacity of about 1200 to 1600 pounds. The barreled material is taken back to the mine by rail, and teamed to Houghton smelters, a distance of 3 miles, where it is refined and cast into ingots, bars or plates, and then shipped East.

The water used in the milling process is obtained from a river near by, across which a dam has been constructed of timber, loose rock and sand. The main portion of the dam is a crib-work built up with hewed hemlock 14 inches thick, securely bound at the joints with 1 inch square drift bolts 30 inches long. The dimensions are: height 48 feet, length at the top 258 feet, length at the bottom 81 feet, width at top 28 feet, and width at the bottom 53 feet, with a perpendicular face up-stream and slope down-stream. The up-stream side of the dam is planked with two layers of boards, one of 3 inches inside and one of 2 inches outside. The crib-work was filled with sandstone, obtained from the banks nearby, while a sand filling was put in front of the planking. A few months after the dam had been filled, it was found to have settled about 10 inches in the center; and the face, which was originally straight across the stream, had curved, at the top, 3 feet down stream. Since then, no perceptible movement has shown itself.

The water is conducted to the mill in a launder 18 inches by 36 inches and 2050 feet long, with a fall of 5 inches in 100 feet. At the mill, the launder discharges into a steel tank 8 feet in diameter and 10 feet deep. A 30 inch cast iron pipe leads from the bottom

of the tank and passes under the floor of the mill, where it is tapped at intervals for supplying the jigs and stamp heads.

This water supply is of the greatest importance to the company, as without it, the chances are that the company would have to suspend operations. When it is taken into account that about 30 tons of water are used in the washing of a single ton of rock, and that this company treats from 1100 to 1200 tons of rock daily, it would be out of the question to lift this large bulk of water with a pump, where the value in the rock is as low as it is at this mine.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881

VOL. XIX. OCTOBER, 1897. NO. 4.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

THE 40-INCH TELESCOPE OF THE YERKES OBSERVATORY.

BY WM. E. REED, M.E., MEMBER THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, July 13, 1897.*]

SOME years ago the University of Southern California, desirous of having a telescope still larger than that of her sister institution, whose observatory was given by Mr. Lick, ordered of the late Alvan G. Clark an object glass which should have a clear aperture of 40 inches, the largest refracting objective attempted up to that time.

Shortly after the order was placed, Mr. Clark visited, in Paris, the works of Mantois, who—partly as the successor of Feil, but largely on account of his own skill in the art—had become so successful and famous as a manufacturer of optical disks, especially of the largest sizes. Here he picked out, from the glass castings which had comprised a portion of Mantois's exhibit at the Paris Exposition in 1889, a crown and flint disk, in his judgment the most perfect to be had. These disks, however, were not destined to be finished for this University of the Pacific Slope; for, soon after the order was placed, both the president of the University and the patron who had offered to provide the glass died, so the lenses remained in statu quo at the works of the Cambridge maker for some time. The train of events, which finally resulted in securing them for the University of Chicago, is not without interest, for it is only another illustration of the fact that often

*Manuscript received September 11, 1897.—Secretary, Ass'n of Eng. Socs.

seemingly trivial incidents are really important links in history's chain. Mr. Clark was attending a meeting of the American Society for the Advancement of Science, held in Rochester, and in conversation with Professor Hale—of whose great interest in astronomy he was well aware, from the results already attained at the latter's own private observatory at Kenwood—mentioned the disks that were still in his possession, and spoke of his desire that some University, that could put them to the best use, should have them finished and suitably mounted, in order that they might be of service in advancing the work of American astronomers. On his return, Professor Hale sought an interview with President Harper, of the University of Chicago, who was much interested in the subject, and together they laid the matter before Mr. Yerkes, with the result, as is well known, that the lenses were purchased, and Mr. Clark was instructed to finish them in the most perfect manner possible. Mr. Yerkes also entrusted the contract for a suitable mounting to carry these precious bits of glass, to Messrs. Warner & Swasey, of this city, whose mounting of the largest refracting telescope until then constructed (the 36-inch on Mount Hamilton) had already been demonstrated a complete success.

The contract for mounting this instrument was given late in November, 1892, and, although at that time there was not a scrap of drawing made toward its design, yet by special effort the instrument was gotten out, and, as many will remember, was exhibited in the main aisle of the Liberal Arts Building at the World's Columbian Exposition in 1893. The lens, of course, was not finished at this time; and, in fact, some of the smaller details of the instrument itself were not completed; yet it was set up in working order, much to the delight of those who were interested in astronomical matters. Neither was the final location of the instrument determined at this time, although it was decided that the observatory should be within a radius of 100 miles from the University of Chicago, and probably in a direction northward. It was of the utmost importance that a place should be found not only sufficiently far away from the smoke of the city and the glare of its lights, so that these elements should not interfere with the observations to be made with the new instrument, but also at a safe distance from the encroachment of the growing city in years to come.

A number of prominent observatories have been located on mountain tops, notably the Lick on Mount Hamilton; and it is often asked whether it is not essential that such centers of astronomical investigation should be placed on similar elevations. While

a mountain has its advantages for such a site, it also has its drawbacks, chief among which is the atmospheric disturbance, caused by the different degrees of temperature to which the air on the opposite sides of the mountain is heated. The reason is obvious, for the sun shines more intensely on one side, heating that surface most, and causing the air above it to rise more rapidly than on the other sides. At the summit it comes in contact with the cooler air, giving rise, at once, to an atmospheric disturbance of no small consequence, which, in certain classes of work, is prohibitive of useful results, and in most cases renders the use of the instrument out of the question for solar observations. Were the location of such an observatory, however, in the midst of an extended plain, the disturbance caused from differently heated vertical strata of air would be very largely done away; and, of course, the matter of a few thousand feet of elevation more or less is of little importance, except that in some cases it takes the astronomer into a region of sky less frequently clouded, or removes him from local disturbances, such as artificial light, dust particles, smoke, etc.

The site finally chosen for the location of the 40-inch equatorial has many of the advantages of a plain. It is situated on the edge of the Big Foot prairie, so named by the Indians, and on the north bank of a small and picturesque lake in the southern portion of Wisconsin. The shores of this lake have for years been dotted with the summer homes of people from the large cities near by; and the location, in all probability, is destined to be always removed from large manufacturing interests. The observatory is about 75 miles northwest from Chicago, on a hill 240 feet above the lake, and 1200 feet above the level of the sea. It is a mile and a half from the village of Williams Bay, which is the terminus of the nearest railroad, and that is but a branch of the Northwestern system. There are no arc lights to disturb the observations of the astronomer, nearer than those of the town of Geneva, which is at the opposite end of the lake, a distance of 8 or 9 miles.

The general arrangement of the building itself—which, with its appointments, is also the gift of Mr. Yerkes to the University of Chicago—was suggested by Professor Hale, the present director, who had spent considerable time in visiting prominent observatories, both in this country and abroad. The designs were given to Mr. Henry Ives Cobb, whose Fisheries Commission Building at the World's Fair will long be remembered, and by him were brought to a most successful architectural issue, without in any way detracting from those purely scientific features, which the

astronomers were so anxious to retain. In general, the building is arranged in the shape of a Roman cross, the long axis being east and west, and having a length of 326 feet. At the west end of the building is the immense tower and dome which houses the great star searcher. At each end of the arms of the cross—which are at the eastern extremity—are small domes for 12-inch and 16-inch telescopes, respectively, while the central portion of the eastern end is designed especially for a large meridian circle room. The arms of the cross extend relatively a considerable distance from the rest of the building, so that the great dome will not prove a serious obstacle to observations in the western heavens from the smaller towers.

The observatory is built of brown roman brick, and ornamented with decorations of the same color in terra-cotta. The pillars, which figure so prominently in supporting the archway of the beautiful central entrances—just alike on both sides—suggest those of the Fisheries Commission Building, in the clever use the architect has made of the grotesque in ornamentation. The central portion of the building is but a single story high, though a large attic extends its whole length, and a well-lighted basement is available for laboratories, and for a machine shop for the construction and repair of such instruments as may be needed at the observatory. Besides these, there are also, in the basement, rooms especially adapted for the necessary photographic work, which has come to occupy so large a place in modern astronomical research. The main floor is divided longitudinally by a beautiful hallway with mosaic floor and marble wainscoting, and is occupied by the director and his staff for offices. There are, besides, some small laboratories, and a well-appointed library, which commands an exceptionally fine view of the lake, and makes an ideal place for quiet study.

As the subject of this paper is more especially connected with the contents of the west tower and dome of the building, a word or two regarding this portion may be of interest. The tower itself is 92 feet in diameter, and is built of masonry to a height of 52½ feet. A balcony, 44 feet from the ground, commands an extended view of the surrounding country, and, together with the special relief work of pillars and arches just below, adds greatly to the beauty of this imposing structure. The dome which surmounts it is 90 feet in diameter, and, contrary to the pattern followed at some other large observatories, a cross-section shows that the dome, while a hemisphere above the plane which includes the center of motion of the instrument, is cylindrical below it for a

distance of 9 feet. This additional height greatly improves its appearance, doing away with the flat and squatty effect which is so evident in domes that are only hemispherical. The frame throughout is steel, and is built up of latticed girders riveted to an immense horizontal circle, also of lattice construction. The dome is supported by 26 wheels, practically of the size and shape of ordinary car wheels without the flanges, and their axles run in special anti-friction roller bearings placed on each side of the wheels. The outside of the journal boxes is spherical in shape, and held in pillow blocks to correspond, thus allowing for self-adjustment and preventing their cramping. The wheels run on 90-pound T rails, which are held on a circular cast-iron supporting ring anchored to the masonry walls.

The dome is covered with wood, tinned on the outside and painted. Instead of the covering being bent to conform to a true spherical shape, the wood work is put on straight; that is, sections through the dome, perpendicular to its axis of rotation, are not circles, but polygons of twenty-two sides each, the corresponding sides of such successive sections being shorter as they approach the zenith. These tapering panels—which do not materially change the shape of a dome from a spherical form—improve its appearance, and provide a more tasteful and satisfactory form of construction. This great dome weighs, complete, 140 tons, and is easily revolved by means of an endless cable, which connects it with the operating mechanism. A circle, nearly of the diameter of the dome itself, made of angle iron, with the inner leg vertical and the other horizontal—forming thus, as it were, a flanged pulley—is secured to the lower inner edge of the dome, and in its groove rests the endless steel cable, which wraps almost entirely around its circumference. At one point, however, the cable is led off and back again tangentially by means of guiding sheaves, from which it runs to the operating mechanism below. This controlling device, carrying with it the great dome, is easily set in motion, either by an electric motor or by a hand rope conveniently placed so that the operator has access to it from the elevating floor, or from the upper balcony.

It is necessary that the dome should be made to revolve, in order that its shutter opening may be brought to a place opposite the objective end of the tube of the great telescope, in whatever position that may be; and to make a dome with a large parallel opening 12 feet wide, extending from the horizon to a point 5 feet beyond the zenith, and to provide for easily opening and closing the shutters which cover it, adds not a little to the interest and

intricacy of the problem. To provide the necessary stiffness for the dome with this opening, two latticed girders, much larger and heavier than the rest, extend from the base ring through the zenith to the base again, parallel to each other and equidistant from the center. These girders are $2\frac{1}{2}$ feet deep at their extremities, and 4 feet at the zenith, and into these great vertebræ the other ribs are fastened, instead of meeting in the zenith, as would be the case were there no shutter openings in the dome. At the base of each of these immense girders are placed trucks, with two wheels instead of one, as is the case elsewhere, for it will readily be seen that the greater portion of the weight of the dome rests at these points. The two shutters, which cover this space, open from the center outward, and are 85 feet long. They are supported on tangential tracks at their extreme upper and lower ends, and they, too, run on wheels with anti-friction bearings, working so easily that a direct pull of 75 pounds will move them. In practice, however, both shutters work simultaneously, and are maintained parallel to each other throughout their entire travel by special mechanism. These great doors are operated by means of a hand rope conveniently placed, and a direct pull of a few pounds only is required to open or close them, though they weigh 9 tons each.

A unique accessory to the shutter—and one which will no doubt be much in use—consists of two canvas curtains which run independently of each other on tracks just underneath the shutter opening and inside the dome. The curtains are placed end to end, their combined length being greater than that of the shutter, and their breadth a trifle greater also. Light and strong steel stays are placed crosswise of the canvas, throughout its length, at frequent and equal intervals, and terminate at each end in trucks, each having two wheels which run upon the special track provided for them. As each curtain can be moved up and down without interfering with the other, and then clamped, it becomes a simple matter to bring the upper curtain to such a place that it will cover the portion of the opening above that through which the great objective is peering, and the lower one till it covers all below it, thus shutting out wind, light and other elements of annoyance to the astronomer, from practically all that part of the opening which is not actually in use.

Having looked somewhat hurriedly at the general arrangement of the building and the outside of the dome, let us now turn our attention within.

The inside of the tower is one great circular room, which one enters upon a level with the elevating floor in its lowermost posi-

tion, reaching it from the broad hallway of the main building by a beautiful marble stairway. At this height there is also the lower of the two balconies, which extend entirely around the inside of the dome, making, when the elevating floor is at its lowest or uppermost position, a continuous floor, 85 feet in diameter. The lower balcony is 21 feet above the basement, and the one above is 23 feet higher, the latter being reached by a narrow iron stairway from the lower balcony, and a similar one also leads down to the basement. The upper balcony is on the same level with the one outside, to which we have already referred, and easy access from one to the other is had by means of four doors with glass sash. There are, however, comparatively few windows in the tower, 4 at the level of the upper balcony, 16 just above the lower balcony, and 13 narrow windows near the ground floor.

One of the most important accessories within the dome, aside from the instrument itself, is the great elevating floor. This is circular in shape, 75 feet in diameter, conforming, with slight allowance for clearance, to the inner diameter of the balconies. In its center, or practically so, is a rectangular opening, of such size that, as the floor moves up and down, it nowhere touches the telescope column. The necessity for having the floor rise and fall is obvious, when one considers that from it the astronomer makes his observations, and that the height of the eye end of the instrument when pointing to the zenith is very different from that when the telescope is directed to points near the horizon. In smaller observatories an observing chair, arranged somewhat like a broad stepladder, and having a sliding seat in the central portion, answers every purpose; but, with so large an instrument as this, it is not only necessary to have the observing chair, but, in addition, to cause the floor to rise and fall, in order to give the observer easy access to the eye end of the instrument. The highest position to which the floor rises is on a level with the upper balcony, and its lowest position is at the same height as the lower balcony, thus giving it a movement of 23 feet. In its uppermost and lowermost positions, it is readily reached from the balconies. For intermediate positions, the stairway, which connects them, and which is at their outer edge, furnishes a convenient means of access to it. The floor is built of latticed steel girders in the shape of a square, which together with the necessary cantilevers, support the practically circular I beam which forms the edge. The girders are covered with pine flooring, laid on spiking strips, and finished with an oiled maple floor, the whole being suspended by steel cables from each of the four corners of the square steel frame-work. These

cables run over sheaves at the top of the latticed columns, in which run the counterweights, and to them the other ends of the cables are fastened. For raising and lowering the floor, cables are run from the operating drums to the under side of the counterweights, and from the same drums to the under side of the floor at each of the respective corners of the framework, thus allowing the floor to be balanced as nearly as possible, since the operating mechanism will either pull the weights down when it is desired to raise the floor, or will pull the floor itself down, in case it is to be lowered. The drums are revolved by worm gearing, and all four of the worm shafts themselves are brought, by means of shafting and bevel gearing, to a common point near the center, where they are operated by a single motor. In this way, the position of the floor is maintained parallel to itself throughout its entire motion, and, owing to the counterbalancing, the motor has little to do beside overcoming the inertia of the moving parts, though the weight of the floor is 45 tons.

Both the floor and the dome above it were designed by Messrs. Warner & Swasey, the execution and details of their plans having been most excellently carried out by the King Bridge Company of this city.

In the center of this great tower rise the pier and column of the telescope. The pier is built upon a concrete base 28x34 feet, 5 feet thick. It is of brick work 20x24 feet at the base, tapering to $15\frac{1}{2}$x$19\frac{1}{2}$ feet at the top, where it is capped by an immense stone coping in four pieces, 18 inches thick, the capstone being 21 feet above the concrete base. Upon this rests the cast-iron column, which is made in five sections, exclusive of the head. The lower section differs materially in shape from the others, and, in fact, is the only one not cast in a single piece. It provides a broad base, tapering by easy and graceful curves in a height of 5 feet from 14 feet by 18 feet at the bottom, to a rectangle 6 feet by 10 feet 4 inches, on which rests the upper and straight portion of the column. The slope of the base is not equal on all sides, however, owing to the fact that the tube and axes above bring the center of gravity much nearer the north end of the column than the south, and the base is, therefore, much broader on this side. It is not only strongly ribbed vertically, but there is a solid support under the portion on which the column rests, extending to the very capstone, and thus securing for the column the greatest rigidity. The upper sections of the column are rectangular cast-iron shells, each about $6\frac{1}{2}$ feet high, and tapering $\frac{5}{8}$ inch per foot. The center of motion of the instrument, in the head which surmounts the column, is $43\frac{1}{2}$ feet above

Fig. 1. The Yerkes Observatory.

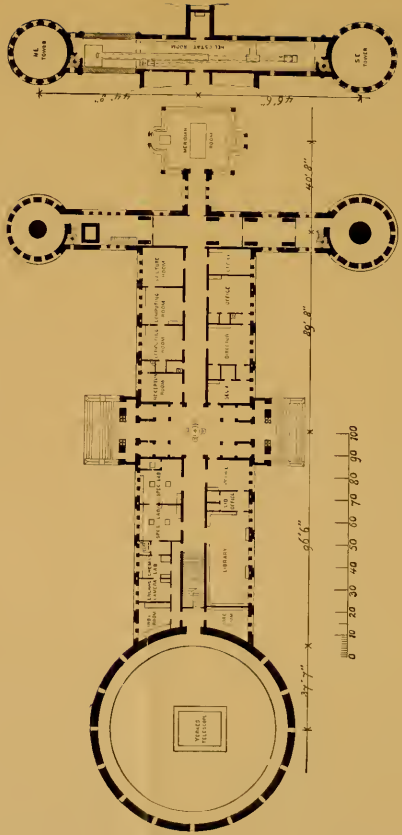


Fig. 2. Main Floor of the Yerkes Observatory.

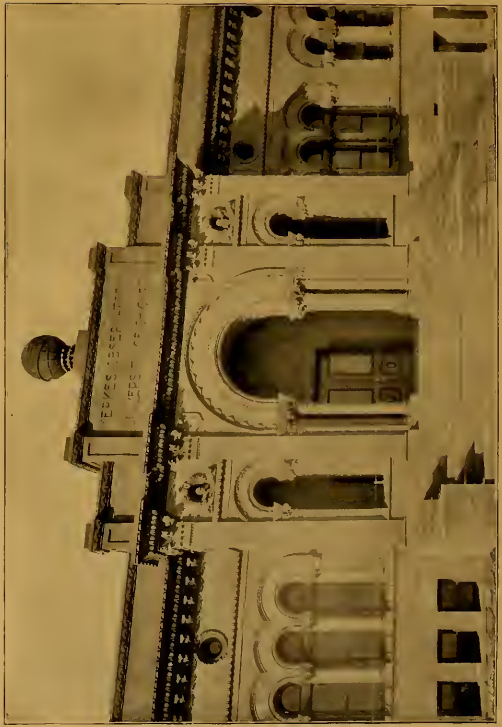


Fig. 3. Main Entrance to the Yerkes Observatory.

the coping-stone of the pier. At the south end of the column is the spiral staircase, extending from the capstone to the balcony around the equatorial head, there being also a landing at the upper section of the column, in which are the driving clock and other accessories.

Having now noticed the supporting column of the great telescope, and its location in the building, let us turn our attention for a moment to that which makes necessary the design and construction of this great astronomical engine—namely, the objective itself. This portion of the instrument is often surrounded with so great a halo of wonderment, emanating chiefly from the imagination of such newspaper writers as are not altogether familiar with its use or construction, that not a few of us are at a loss to know what it is lawful to believe, and what is purely fiction. It may, therefore, be of interest to speak briefly of the lens itself, and of its transportation to the observatory. As has already been widely heralded, the lens and cell were brought from Mr. Clark's factory at Cambridgeport, Mass., in a Pullman car. They were the contents of three large boxes about 5 feet square, and from a foot to 18 inches thick. The smaller boxes contained the lenses and the larger one the cell, in which they were to be held. The objective is composed of two lenses, a crown and a flint. The crown lens is double convex, and is $2\frac{1}{2}$ inches thick at the center, and $\frac{3}{4}$ inch thick at the edge; while the flint, which is practically plano-concave, is 2 inches thick at the edge and $1\frac{1}{2}$ inches at the center, both lenses being $41\frac{1}{2}$ inches in diameter. Each lens was wrapped in the finest and heaviest felt, which was sewed around the circumference, and then covered with tough wrapping paper, glued at the edges to prevent dust and dirt from working on to the surface of the glasses themselves. These parcels were packed in the boxes referred to with an abundance of curled hair, some of which had served a similar purpose in the transportation of the Lick objective, but—newspapers to the contrary notwithstanding—there were no springs for supporting the lenses other than the abundant mass of spirally curled hair. The cell is a cast-iron ring, flanged at the inner edge, and has a corresponding flange at the outer edge. The portion of the ring between the flanges is perforated with seven equally spaced elliptical holes, to allow for ventilation and for cleaning the lenses; but a circular band or shield of brass is so arranged that these ventilators are easily opened or closed at will. The glasses, when placed in the cell, are each supported at three points on aluminum bearings, and are separated by a distance of $8\frac{3}{4}$ inches. After the lenses were unpacked and were carefully dusted with a camel's-hair brush, and

after the operator had wiped them clean with a fine cotton cloth, breathing on them now and then to supply a little moisture, Mr. Clark asked three or four of the gentlemen present to carry them in their hands and place them upon the simple and ingenious jacks which were provided for lowering them into the cell. Mention is made of this trivial fact, because one often reads—in the ever-present newspaper—of the ruinous effects of barely touching optical work.

The cell and its lenses weigh about 1000 pounds, and to support this precious weight rigidly, and to make provision for observing and for magnifying the real image which it brings to a focus 61 feet away, as well as to enable the astronomer to point it at will to any object in the heavens, is the problem that confronts the engineer; nor is this all, for jarring and vibration vitiate observation, and from these the instrument must be free. To support this cell and its lenses, a great tube is made, 59 feet 3 inches long. It weighs six tons, and is built up of sheet steel in five sections, or four tubes of nearly equal length, and a central one which is short, but very strong. Each section terminates in a steel flange, faced true, thus furnishing means for bolting the several tubes together in accurate alignment. All rivet holes were drilled, the steel plates being bent about special forms for the purpose. The central section is 52 inches in diameter, and from it the tube tapers slightly, in both directions. It not only has the steel flanges at the edge, but several steel rings inside to stiffen it, and to provide means for attaching it to the declination axis.

The cell is bolted to the corresponding flange at the end of the steel tube by means of six bolts, arranged in pairs, each pair being equally spaced with reference to the others, around the circumference, and between the two bolts of each pair is an abutting screw, so that the cell actually rests on three points, thus bringing the least possible strain upon the lenses themselves, and providing accurate collimation.

The declination axis, to which the tube is bolted, is held in an immense sleeve of cast iron, which, in turn, is bolted to the upper end of the polar axis, at right angles to it, and at a position as near to the tube as possible, so that a minimum weight at the end of the declination axis shall, with its long leverage, balance the weight of the tube about the polar axis. To accomplish this, a long brass screw, with heavy steel center, is fastened to the end of the declination sleeve, and carries circular cast-iron weights of about 225 pounds each, which can readily be moved backward and forward upon it, to allow for changes in the weight of the acces-

sories used upon the tube itself. The polar axis is held in immense bearings in the equatorial head of the column, and its angle of inclination corresponds exactly to the latitude of the observatory where it is located.

The polar axis has no motion except one of rotation in its bearings, but the declination axis, which is at the upper end, not only has its motion of rotation, carrying with it the tube, but is itself rotated about the polar axis. Thus it will be seen that the tube has two distinct motions, one on the declination axis, which is nearly midway of the length of the tube and at right angles to it, and the other on the polar axis, which carries the declination axis and the tube. Since the polar axis is parallel to the axis of the earth, it is evident that if it is given an angular motion equal to that of the earth, and opposite to it in direction, any portion or extension from it will maintain unchanged its position relative to fixed bodies beyond our sphere; and, the axis being fixed, it becomes a simple matter to fasten to it suitably a large worm wheel, and to drive the worm by clockwork, thus giving the tube a motion corresponding to that of the earth. To drive the instrument at such a rate does not require very great power, even though it has to move a mass of 20 tons, for it turns it at the rate of but one revolution in a siderial day of 23 hours, 56 minutes, 4.09 seconds.

Both of the axes of which we have been speaking are made of steel, the polar axis being 15 inches in diameter, 13½ feet long, and weighing 3½ tons, while the declination axis is 12 inches in diameter, 11½ feet long, and weighs 1½ tons. They are both hollow steel forgings; for, in order to secure the necessary automatic motions of the tube, to be described later, shafts transmitting this motion must be brought through their centers to the necessary gearing.

Both axes are held in great babbitt bearings; but, to relieve them from unnecessary friction, live rings, or anti-friction roller bearings, are so arranged that they take the greater part of the weight, the babbitt boxes serving chiefly the important part of maintaining the axes always in their proper positions. The roller bearings for the larger (polar) axis can be adjusted once for all, since its position is fixed, but in the case of the declination axis these roller bearings must support the weight for positions which are constantly changing. To arrange for this, an ingenious system of compound levers is provided, which not only supports the weight through a plane, but in any position through 360°. By

compounding the levers, the necessary actuating weight is reduced to a minimum.

The clock which drives this instrument is placed in a section just below the head; it is driven by a weight of about 1½ tons, suspended by a steel cable from a grooved drum. This drum, by means of the necessary gearing and shafting, revolves the worm, to which we have already referred, and it in turn revolves the worm wheel fastened to the polar axis. The clock is governed by a double conical pendulum mounted isochronously, and the balls of the pendulum are so arranged that rotating them on their axes furnishes a means of slightly altering the speed of the clock; but, after the proper rate is once found, it is rarely necessary to change them, for the gearing is in triplicate, so that either solar, lunar or siderial time can be secured by making the proper change. To do this, it is necessary only to turn a lever to the proper position on a dial. The clock weight can easily be wound by hand, but an electric motor, so arranged that the weight cable operates its switch, starting it when the clock is nearly run down, and stopping it just before it is fully wound up, is still easier and less liable to be forgotten. This form of clock governs the speed of the instrument with wonderful exactness, and that under great changes, since it must readily maintain its own speed constant, either when merely running alone, or when carrying the whole movable mass of the instrument, for during the astronomer's observations, the clock must be ready at any instant to keep the telescope pointed to the object which he wishes to follow.

Simply to mount a mass of 20 tons, distributed as this is, so that the observer, at the eye end of the tube, should be able to move it at will to positions within the range of his reach, would be a comparatively easy task; but much more is required. The observer must be enabled readily to point the objective to the zenith and again to the horizon, either on the east side of the column or on the west, and the various positions through which the eye end travels, ere it reaches the desired location, are such that it would be impossible for the observer to push and pull the big tube through more than a limited space. For this reason, there are placed at the north end of the column, where they can be easily reached by an assistant standing in the balcony, two hand wheels which resemble those in the pilot box of a small yacht. By means of shafting and gearing, a few pounds' pressure on one is sufficient to turn the tube on the declination axis in either direction; or, by turning the other wheel, motion is given to the tube on the polar axis, so that, from the balcony, one can at will point the great tube

toward any portion of the heavens; and, for his aid in so doing, coarse and fine circles are provided on each axis indicating the degrees and hours—celestial latitude and longitude—of the space toward which the tube is pointing. In addition to these "quick motions," by hand, two electric motors, which are placed in the clock room, are so arranged, by special gearing, that they will also move the tube in either direction on either axis. Reversing switches, especially designed for the purpose, are placed near the hand wheels in the balcony, where they can be easily operated by the assistant, or by a special device from the elevating floor. These switches are provided with stiff springs, in such manner that when the operator releases his grip, they automatically throw out. Resort was had to this device, lest otherwise the motors might some time be left running and carry the tube too far.

The motions thus far mentioned, except that of the clock, are for rough-setting the instrument; that is, for pointing the tube approximately to the desired spot. When this has been found, the tube is clamped in position; that is, by devices not yet mentioned the tube is fastened to the declination sleeve, so that it no longer turns freely on its axis, and the polar axis is clamped to the worm gear, driven by the clock. It, therefore, remains for us to describe the slow motions by which the operator brings the object into the center of the field.

This mechanism is the same in both right ascension and declination; therefore, let us confine our attention to that in declination.

A large ring, the inner edge of which is wedge-shaped, fits into a corresponding groove on the declination sleeve, the groove being in a plane at right angles to the axis and near the tube end of the sleeve. From one side of the ring there projects a long triangular arm, the base of which is attached to the ring, and the apex terminates in a suitable device for holding a special bronze nut. On the tube, two brackets support a bronze screw, which passes through this nut, thus connecting the lower portion of the arm with the tube, though in such a way that, if the arm were held stationary, the tube could be given a slight angular motion with relation to it, by moving the nut along the screw; but, when the arm is not held fast, the ring turns freely in its groove, allowing the tube to turn on the declination axis, carrying the ring and arm with it. Since the sleeve, on which the ring revolves, is stationary with reference to the declination axis, it is not difficult to clamp the ring to it. To accomplish this, a few inches of the wedge-shaped portion of the ring are cut away, and a movable bronze wedge is substituted. A screw forces the wedge forward, clamping the ring

to the sleeve, and shafting and flexible joints connect the screw with a hand wheel at the eye end of the instrument, so that the observer can readily operate it from that point. A precisely similar arrangement allows him to do the same for the polar axis, although, in that case, as already mentioned, the ring is clamped to the worm wheel, which is revolved by the driving clock. These clamps are, however, operated electrically as well as by hand. A pair of bell-cranks is placed at the wedge, and to one of the long arms is attached an electro-magnet, especially designed for the purpose, and capable of pulling from 1000 to 1500 pounds. To the other arm is fastened its keeper. In operation, the magnet brings the long levers of the bell-crank together with great power, and the short ends, pressing outward, force the wedge into its groove as the screw does. After the instrument is clamped, the long arms of the bell-crank are held together by a latch, so that it is not necessary to keep the current on the magnet for more than a moment. To unclamp the instrument, another pair of magnets, precisely similar to those just described, is provided, for releasing the latch. That these magnets may be easily operated, suitable switches are arranged at the eye end of the tube, within convenient reach of the astronomer, who has merely to press a key in order to operate them. If he prefers, however, the hand wheel and screw are at his service, for each method is entirely independent of the other.

After the instrument is clamped, turning either of two other hand wheels at the eye end, similar to those just referred to, and similarly placed, revolves the bronze screw of either slow motion arm in either direction, thus producing slight angular motion of the tube on the declination or polar axis.

In this instrument, however, there is still another means at command for securing slow adjustment. Especially designed slow-speed motors are so arranged that they will revolve the nut of the slow-motion arm, while the screw stands still, thus giving an independent means of obtaining precisely the same results as are secured when the screw is revolved by the hand wheel. The motor, however, has great advantage over the hand wheel, for the astronomer need only press a button, which is much easier to reach, to let subtle electricity do the rest. The press-button switches for controlling the slow motions and clamps, like those for the quick motions, are provided with springs, so that the mechanism which they operate is in use only so long as the switch is held closed.

Not a little ingenuity is displayed in bringing a cable, containing the fourteen separate wires for operating the clamps and motors, from the stationary portion of the column to the movable declination sleeve, and from the sleeve to the tube, which in turn

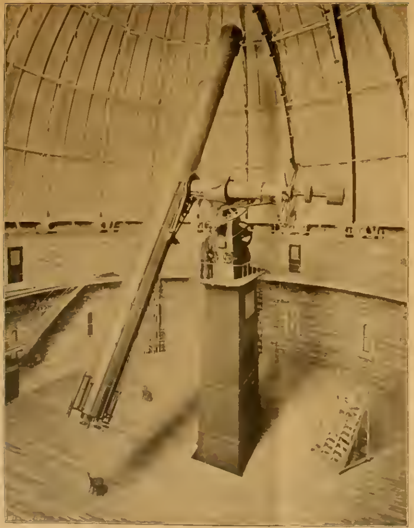


Fig. 4. 40-inch Yerkes Telescope, May 1897.

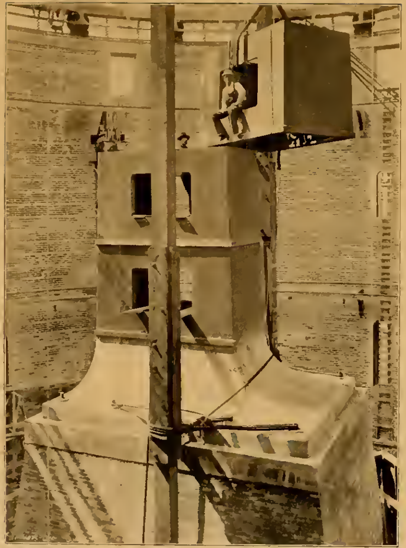


Fig. 5. Erecting the Iron Column of the Yerkes Telescope, September, 1896.

Fig. 6. Erecting the Polar Axis of the Yerkes Telescope October, 1896.

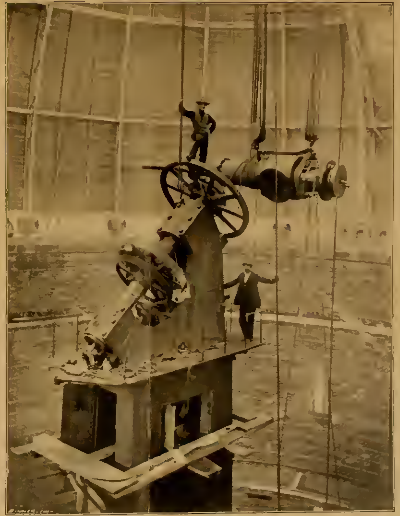


Fig. 7. Erecting the Declination Axis of the Yerkes Telescope, October, 1896.

moves in relation to the sleeve, and from there down to the eye end of the instrument; for this must be done not only in such a way that the wires will distribute the necessary current, so hard to keep within bounds, but so that they will in no way interfere with the motion of the instrument, nor be in danger of catching and breaking asunder.

We have already spoken of the electric motors which revolve the dome and raise or lower the observing floor. These also will be controlled by switches on the elevating floor, within easy reach of the observer. When one switch is closed, the great dome turns until its mammoth shutter opening commands just that view of the heavens which the astronomer desires. When other switches are closed, the tube moves this way or that on its axes until it points approximately to the desired spot. The closing of another switch causes the floor to rise or fall until it reaches the right height for the most convenient observation. The observer touches a button at his fingers' end, and the instrument is clamped, so that the clock, from that moment, carries the tube steadily forward, keeping it upon a single point in the heavens, regardless of the motion of the earth. He touches another, and the slow motions bring the object of his search into the very center of the field of the objective.

It is partly in the successful application of electrical devices of this sort that the 40-inch telescope of the Yerkes Observatory differs mechanically from any heretofore constructed, and it is with eager interest that the face of the astronomical world is turned towards this new observatory and its corps of able astronomers; to this instrument—this princely gift to the University of Chicago—which now stands without a rival: as it were, a court of last appeal; a telescope which not only has an objective with light-gathering capacity 25 per cent. in excess of the largest hitherto made, but which is even more perfect in the simplicity of its design and the uniqueness of its equipment.

It was said of the great telescope of the Lick Observatory that the limit had been reached, that no larger instrument would be made; but, standing in the light of the accomplishment of the present, let us be profoundly grateful that it is given to man to demonstrate that the impossibilities of yesterday are the achievements of to-day, and let it be with the utmost caution that we place limitations upon the future.

The author is indebted to Prof. E. E. Barnard for the photograph from which the general view of the observatory was made, and to Prof. George E. Hale, director of the Yerkes Observatory, for enabling him to secure electrotypes from the University of Chicago Press for the other illustrations.

HYDRAULIC DREDGING: ITS ORIGIN, GROWTH AND PRESENT STATUS.*

By W. H. Smyth, M.E.

[Read before the Technical Society of the Pacific Coast, October 1, 1897.†]

"Balme made a vertical wheel, which worked between two boats, armed with six buckets, which lifted a vast deal of mud."

Probably not more than one out of the hundreds who have read this statement in Cresy's "Encyclopedia of Engineering" have given it a second thought, or seen in it more than a simple statement of a not very important historical fact. To that one, however, it was the hint, suggestion, inspiration or what not, which completed a work of years and gave to man another tool wherewith to mold the face of the earth, and to the world a new art—hydraulic dredging.

Every new art is the product of a growth and development to which the work and intelligence of many have contributed. Sometimes the development is extremely gradual, so that to no one man more than to a thousand others can credit be accorded. And again, in the life and labor of one man the scattered and disconnected influences combine with favorable conditions and bring about the same result with an appearance of suddenness. In either case the process of development is the same. To the latter of these two classes belongs the subject of this paper.

Misconception and much confusion of mind are apparent in the discussions of the subject by practical men both in and out of the courts. This is almost wholly due to misunderstanding as to what is and what is not embraced in the subject. A definition, therefore, it is hoped, will clear the way for an intelligent and connected discussion, and avoid the necessity of numerous explanations later.

The art of hydraulic dredging involves: (1) The mechanical severing of material from a water bottom; (2) the lifting of the severed material therefrom by atmospheric pressure; and (3) the transporting of it (mixed with water), by mechanical pressure, through pipes to any desired place of deposit, these three processes constituting one continuous and connected operation.

* Copies of this paper were sent to the several parties to the hydraulic dredger litigation, with invitation to be present and discuss the paper. The illustrations are in part from photographs of well-known machines and partly from the records of the courts.

† Manuscript received Oct. 27, 1897.—Secretary, Ass'n of Eng. Socs.

To review briefly the salient points in the progress of this art is the object of this paper.

The historian, looking backward, can trace the growth of institutions and note the trend and importance of past events affecting this growth, which, to contemporaries, appear trivial and without significance. As with such institutions, so is it also with the evolution of an art.

Scattered along its pathway can always be seen hints and foreshadowings, devices frequently foolish and impracticable, as viewed in the light of later knowledge, though at times almost prophetic; others again lacking but one little ray from that light to illumine the step that separates success from failure.

The art of hydraulic dredging is no exception to this rule.

Prior to 1878 the only forms of dredgers in use for handling hard material were the dipper, the clam-shell and the endless chain bucket. These might all be classified under one head, in that their action is purely mechanical. While differing in detail of construction, they all work on substantially the same principle, viz: that of scooping the spoil from the bottom and dumping it on shore or into lighters alongside.

Though these are so well known and their names so peculiarly appropriate that a detailed description here would be out of place, yet, for continuity of the discussion, a few words of explanation will be given to each of these devices.

The dipper dredger is characterized by a huge bucket or dipper, having a capacity of from 1 to 5 cubic yards, the handle of which is a beam of wood or iron 20 to 60 feet in length, mounted and guided on a projecting arm or boom. Operating chains are provided whereby motion is given to it practically identical to that of its humble namesake, if used to scoop sand from a shallow pool and dump it into a bucket close by. To obviate the undesirable necessity of reversing a dipper of such large size to free it of its contents, the bottom is hinged and opens to discharge the spoil.

The excavator of the clam-shell dredge, in its most simple form, consists of a semi-cylindrical bucket, made in two halves, which are hinged together along the axis of the cylinder, thus forming jaws opening outward and upward. This bucket is attached to chains or poles, whereby it is lowered, with its jaws open, into the mud bottom. The closing of the jaws scoops the mud, and, when the bucket has been hoisted and swung over the lighter, opening the jaws discharges the contents thereinto.

The endless chain bucket, a more elaborate device, differs

from both the preceding, in that its operation is continuous. The main feature of its excavator is an endless traveling chain passing around a pulley or tumbler at each end bight. To this, chain scoops or buckets are attached at intervals. The chain, with its tumblers, is mounted upon a sloping frame, called a ladder, pivoted at its upper end; thus the buckets at the lower end are dipped in the mud bottom, and by the travel of the chain each bucket is successively filled, raised and discharged of its contents.

Each of these devices is, of course, mounted upon a floating barge or boat.

Dredging operations are often carried on at a distance from the shore, so that provision must be made for disposal of the excavated material. In connection with the devices just referred to, this function is usually performed by scows or lighters. In canals and similar places, where the distance to shore is not great, though too far for the unaided dredge, a flume or suspended spout has been sometimes employed.

In technical literature, extending back to the remote past, are numerous suggestions of other forms of dredging devices. Wheels of large diameter, provided with cutting and lifting devices, have received much attention, and many attempts to construct practical dredgers on this plan have been made. Perhaps the most notable of these was the Fondé and Lyons dredge, well named "Leviathan." This was built in New York about 1858 or 1859. It consisted of a wheel about 60 feet in diameter, mounted like a huge paddle wheel in a longitudinal slot amidships of a boat, and so arranged as to be raised and lowered by screws. Upon its periphery were large parallel-sided boxes for scooping the mud. This device, when put in operation, developed at least one unexpected result. In making the first cut its work was beyond criticism, but all efforts to make it take a second cut parallel to the first proved abortive. When started on a second cut the dredge would crowd over toward and across the first and attack the opposite bank, until the same influence started it back again, thus making a zigzag cut, back and forth across the first one. This difficulty appears to have proved insuperable, for nothing has since been heard of the device. Wheel dredgers have been very attractive to inventors, owing to their recognized capability for cutting and lifting spoil. The inherent difficulty of handling and managing them has, however, always proved a stumbling-block to success.

As far back as the knowledge of "suction" pumping extends, it has been known that sand and fluid mud would come up in

pumping when the suction pipe met with such material, and sand pumps, based upon this knowledge, have not infrequently been constructed.

Soon after centrifugal pumps attained commercial efficiency, their adaptability to this class of work was recognized. The condition of knowledge in this line a generation back is well illustrated in the following extract from *Engineering* (London, England, January 1, 1869):

"In a recent number we gave a description of a centrifugal "dredger now in course of construction at Messrs. Gwynne & "Co.'s works, and having been favored with a copy of the working "drawings, we are now able to lay before our readers all the "details of this interesting machine.

"In order to describe it fully, we must repeat the principle "of action of the centrifugal dredger, in the design of which "Messrs. Gwynne & Co. have been guided by the experience "obtained from the working of their well-known centrifugal "pumps. . . . In their large pumps used for draining lakes "in Holland, Denmark, etc., fish, like carp and eels, sometimes of "considerable size, have been sucked in and discharged unin-"jured. . . . Sand and mud properly mixed, with about half "the volume of water, have been also lifted, and often pumps have "been constructed solely for that purpose. . . .

"The *applicability*, therefore, of the centrifugal pump for "dredging purposes had been established beyond a doubt, and it "was necessary only to give it a form suitable for the requirements "of the case. . . . We have been informed that centrifugal "pumps have been in use for deepening the bed of the Mississippi.* "There the telescopic suction pipe of a pump, fixed on a barge, "was driven two feet into the sand, and the water, on being drawn "in and washing up the surrounding sand, formed a sort of hole. "The barge was then removed to another place and the operation "repeated."

Still earlier than this, viz: in 1856, Louis Schwartzkopff, a German, took out, in England, a patent on a device which foreshadows in a remarkable manner the modern hydraulic dredger. An inspection of his drawings renders irresistible the conviction that, had his knowledge of the conditions involved in the problem equaled his ingenuity, the art of hydraulic dredging would have entered upon its career of usefulness a quarter of a century earlier than it did. It does not appear that this device was ever put into

* The writer has been unable to find any other record of this Mississippi sand-pumping.

operation, and a careful examination of the patent shows that, without material changes, such an attempt must have proved fruitless.

There are records of many other devices which vaguely show, on the part of their originators, a more or less perfect appreciation of the availability of individual elements now employed in hydraulic dredging, but their importance in this connection does not warrant more particular consideration. For all practical purposes, the devices which have been described include everything within the state of the art bearing directly upon the subject of hydraulic dredging at the date when this method was first put into operation.

Around the Bay of San Francisco there are vast stretches of shoal, swamp and overflow land, consisting of alluvium of great depth and extraordinary fertility when reclaimed. It is not surprising, therefore, that attention was early turned to the consideration of means for the reclamation of this rich domain. The necessity for opening and deepening navigable channels in the shoal tide lands on the eastern side of the bay gave added impulse to the construction and improvement of dredging devices on this coast. Under these favorable conditions dredgers of the types described soon reached, in California, a very high, if not the highest, degree of improvement in construction and efficiency. It is important, in the present connection, to note that, though the devices for severing and lifting spoil were thus brought to a high degree of excellence, that other and almost equally important factor in dredging, *means for the transportation and disposal of the dredged material, had for some reason been neglected, and remained far behind the others in efficiency.*

This was the condition of affairs when hydraulic dredging came upon the scene.

We must now go back a generation. In 1853, at Shaw's Flat, Tuolumne county, Cal., a series of experiments were made by a young engineer to determine the capacity of flowing water to transport sand and earthy material in open conduits, and its availability in the construction of dams in mountainous districts. Ten years later the necessity of levees for the low-lying lands along the Sacramento river became a subject of pressing and daily consideration. Recalling his early investigations, he gave the subject much thought, and soon afterward took up the experiments again, "to see whether it was feasible to take material from the Sacramento river, and, with a low head of water, put it on the banks for the purpose of building levees."

In these later experiments a pipe was used; it was provided

with a low hopper for the reception of material to be transported, as in the device shown three years later in the English patent 286, of 1866, issued to James Robertson. It was found that by elevating the hopper to form a "pressure column," with a rapid stream flowing through the pipe, sand could be transported a long distance up a slight incline or for a short distance up a much steeper incline to a point considerably higher than the top of the pressure column.

In the event of these experiments proving the feasibility of this method of transportation, it was contemplated to employ it in conjunction with a clam-shell or chain bucket dredge, the aim being *to raise the transporting function to a par with the efficiency of the severing and lifting devices* of the dredgers then in use; and, further, to do this in such form that distance across water would not act as a bar to its use, as it would, for instance, with an open conduit or with a closed one dependent solely upon gravity.

In these experiments a result was observed which for a time threatened the utility of the whole scheme, and did, in fact, very materially affect the ultimate outcome. It was found that, though rapidly flowing water in a pipe constituted a transporting agent of great capacity, the outflowing stream distributed the material over an extremely large area, so that as a means for forming embankments or building levees it seemed hopelessly unavailable. To overcome this difficulty without detracting from the commercial utility of the method, numerous expedients were tried, with but meager results until it was observed that sand and water do not move in a pipe as a homogeneous fluid, and that the sand travels below the water. This suggested cutting holes in the bottom of the pipe at some distance from the end. The solid matter was thus almost perfectly separated, and the capability of the device to produce levees of excellent contour fully demonstrated. This was in 1863.

During the course of these investigations it became evident that a principle was involved which reached beyond the immediate goal of the experiments. As a transporting agency the device not only surpassed expectations, but also *far exceeded any dredger then known in capacity for supplying spoil.* Thus the dredging and transporting functions had changed places in point of comparative efficiency.

To produce a combination in which the device for excavating and raising the spoil would equal in capacity the capability of the transporting device to dispose of the material, and thus form "an ideal dredge," was a problem to which the following eight months

were devoted. Operations meanwhile were suspended on the levee proposition, pending the issue of the later and more important undertaking. Pursuing, with untiring persistency and thoroughness, every avenue which might lead to the object sought, the young engineer made himself familiar with the history and state of the art in dredging appliances. In the course of this investigation, on the 12th of July, 1864, in the Mercantile Library of San Francisco, he read the statement with which this article opens. The words, "lifted a vast deal of mud," arrested his attention. They perfectly expressed the device so earnestly sought. For the remainder of the day and far into the night a bucket-wheel which would "lift a vast deal of mud" engrossed his thoughts. Was it possible to combine, in practical form, an excavator wheel with the new transporting device, when all past experience with like excavators pointed only to failure? Before morning, however, the design for such a combination became clear. Two sketches, made early on the following day, present the result, and the memorandum thereon gives naive expression to his satisfaction thereat. This sketch, which has occupied an important place in the subsequent dredger litigation, was made upon a piece of common brown wrapping paper, and, though but rough in execution, it undoubtedly shows every essential element of the modern hydraulic dredge. One point in the memorandum, it should be noted, referred to as "this principle of inward delivery," has been a subject of much disagreement and controversy between mechanics and experts. The records show no suggestion, prior to this, of a rotary excavator in which the material, when severed, thereby passed interiorly to a suction pipe, or which had, to use the phrase hackneyed in this connection, "inward delivery to a suction pipe."

During the long period of years since 1864, hundreds, if not thousands, of models, drawings and sketches have been made by the inventor, most of which, in the natural order of things, have been lost or destroyed. More than enough remain, however, to make difficult a selection of those which most fittingly show the growth of the invention into mechanical form.

From 1868 to 1876 he was particularly active in his endeavors to get the invention into practical operation, only to meet with disappointment and delay, though many times on the verge of success.

Somewhat discouraged by lack of success in persuading practical men to put money into the enterprise, he decided to protect the invention. The records show that an application for a patent

was prepared, and also a receipt for money paid thereon, dated August 22, 1872. In December, 1876, application for patent was filed. On April, 1877, allowance was reached, which contained twenty claims. The allowance of these claims had been procured and amendments made without consultation with the inventor, and apparently without due consideration of the importance of the subject-matter. When made aware of the nature of the claims, he refused to accept or issue the patent, and permitted the application to lapse. In 1879 this application was renewed, in accordance with the provisions of the law in such cases. This renewal dragged along in the Patent Office until June, 1882, when the power of attorney was revoked by the following characteristic letter:

613 Mission Street,
San Francisco, June 13, 1882.

To the Commissioner of Patents, Washington, D. C.:

Sir: Unable to fee attorneys to prosecute my cases at the Patent Office, they hang fire while I grow gray. It becomes necessary for me to do the best I can with them myself. The power of attorney heretofore granted by me to Messrs. ———, of San Francisco, and Messrs. ———, of Washington, D. C., is hereby revoked in the case of the renewed application for improvements in dredging machines. Ignorant of the changes that may have been made in the specification or drawings, I enclose $5 for contents of the file wrapper. I cannot give the number.

Respectfully,

A. B. Bowers.

From this time on he prosecuted his own case, with the result that the one application, with its twenty claims, was divided into eleven divisional applications, all of which were allowed in due course, and issued with an aggregate of 363 claims. He has since taken out other patents and has other applications pending.

Prior to this, however, in 1878, A. E. Davis, president of the South Pacific Coast Railroad, was induced to advance money for the construction of an experimental machine under the supervision of the inventor. This dredge was built entirely from second-hand material picked up here and there. The dredge boat was an old mud scow, and upon it was mounted a 40-horse-power engine, connected to drive a centrifugal pump having a runner 27 inches in diameter. The suction pipe, with its rotary excavator, was rigged outboard along one side, and the discharge pipe consisted of a number of lengths of 14-inch pipes, on floats, connected into a continuous flexible pipe by short lengths of leather hose and 200 feet of canvas hose, reaching to an enclosure on shore.

Notwithstanding these disadvantages, and the fact that the

canvas hose frequently burst, the device handled a large amount of thick mud. The operation of this machine was witnessed by a number of prominent persons and government officials, who have testified to these facts. One of the spectators was so impressed that, in a letter written at the time to an Eastern correspondent and referring to the machine, he said: "It can dig mud faster than any three machines I ever saw."

This was the *first* application of the modern art of hydraulic dredging.

Thus, after fourteen years, came the fruition of long endeavor. A device had been achieved which not only severed and "lifted a vast deal of mud," but also deposited it on shore in one continuous operation. The work of the inventor was done. His "faith in the combination of elements," shown in 1864, was demonstrated to have been well founded. The further declaration of intention "to patent and profit from it" still remained to be accomplished.

Hydraulic dredging now began to be appreciated as an important factor in reclamation and similar works. The time had arrived when practical men needed no persuading to invest money. Results—the sum of all good to the practical mind—were now in abundant evidence, and those of practical mind were not slow to take advantage. A couple of years previously Col. Allexey W. von Schmidt had constructed, for the purpose of levee building on the Sacramento river, a large sand pump, mounted upon a barge and having a suspended pipe to convey the sand ashore. It was also provided with a propeller-shaped rotary implement in the flared mouth of the suction pipe. This was afterward remodeled by the Golden State and Miners Iron Works by incorporating the rotary cutter with inward delivery, the floating discharge pipe and other hydraulic dredger devices. This remodeled machine became known as the Williams & Bixler "Atlas" dredge.

Improvers, and "inventors" too, found a new field for the exercise of their skill, and took up their task in the evolutionary process. Pumps for hydraulic dredgers, rotary excavators with inward delivery, floating pipes with flexible joints—all these and many other details became the subjects of numerous patented inventions.

It was not long, therefore, before hydraulic dredges were at work, each differing slightly from the others and from the designs of the original inventor, though incorporating, in different forms, the essential characteristics disclosed by him.

In 1883 Von Schmidt built another machine to execute some extensive dredging contracts. He was, in fact, the first to put this new method to the test of commercial competition with the older form of dredges. Profiting by his experience with the earlier machine, he made changes, which he covered by patents No. 277,-177, May 8, 1883, and No. 300,333, dated June 10, 1884. With this machine he used a floating and jointed discharge pipe. The excavator was a rotary one with inward delivery. The San Francisco Bridge Company also built dredgers upon the new plan, and with them "lifted a vast deal of mud." Others, also, both in California and elsewhere, showed their awakened appreciation of this method by building and using hydraulic dredgers.

Now commenced the era of litigation, through which every new device of value must pass.

Owing to the saving effected by the hydraulic dredger, the great cost of each machine and the magnitude of the undertakings in which they are employed, the dredger litigation has been stubbornly, persistently and most ably contested, and has taken a place, both in importance and interest, in the front rank of patent causes.

The amount of testimony taken has extended into thousands of printed pages; wagon loads of exhibits have been employed in illustration; the libraries and patent archives of the world have been ransacked during the past decade in this war of interests.

In 1888 suit for infringement was commenced against A. W. Von Schmidt by Alphonso B. Bowers. An interlocutory decree was rendered in the Circuit Court by Judge McKenna (now Attorney-General of the United States). This decree was affirmed on appeal by the United States Circuit Court of Appeals, January 4, 1897. As a last resort, an endeavor was made to reopen the case by application to the United States Supreme Court for a writ of certiorari on certain points of patent practice claimed to be unadjudicated, but without avail. The writ was refused, and this case was thus settled beyond appeal.

A few months earlier, in 1888, suit was commenced against Williams & Bixler and others, having reference to Von Schmidt's first machine as remodeled. This, after the testimony had all been taken, was settled by compromise, payment of damages and entry of interlocutory and final decrees in favor of Bowers.

Suit was commenced against the San Francisco Bridge Company, March, 1893. In this case testimony is all in, and it has been argued and submitted to Judge W. W. Morrow, of the United States Circuit Court, for decision.

Bowers *vs.* Pacific Coast Dredging and Reclamation Com-

pany and John Hackett was commenced September, 1894. Preliminary injunction was granted in this case by Judge W. W. Morrow.

Bowers *vs.* Alexander McNee and others.

This case was settled by compromise, entry of final decree in favor of complainant and payment of damages.

Bowers *vs.* New York Dredging Company and San Francisco Bridge Company. This suit was commenced at the city of Tacoma, Wash. A preliminary injunction was granted therein by Judge C. H. Hanford, United States District Judge.

Other suits are pending and to be commenced.

The position taken by Bowers in these suits is that he was the first to devise:

(*a*) A rotary excavator with inward delivery through itself to a suction pipe.

(*b*) A floating discharge pipe which would transport the spoils from a dredger over the water and deliver them to any desired point on shore.

(*c*) A machine to dredge on a circular arc while the boat oscillates on a self-contained pivot and acts as a rigid radius holding the cutter to its work.

(*d*) A machine to make an arc-shaped cut with an excavator while the boat is oscillating on a self-contained pivot, and then to move the machine ahead and make a second similar arc-shaped cut, and so on thereafter continuously, until a clean, smooth bottom is dredged.

(*e*) A machine to cut and sever material in place at the bottom of a waterway with a rotary excavator having side feed and inward delivery, carry the material inboard by suction and then force it through a flexible pipe, floating on or submerged under the water, to any desired place in the water or on shore, to be used for filling purposes, if desired.

In the Von Schmidt case the defendant first denied each and all of these claims, and contended that he (Von Schmidt) was the first inventor of the hydraulic dredge and the first to put it into practical use; that the Davis dredge of 1878 was impracticable, useless and inoperative; but later he introduced patents antedating his own invention, and questioned the validity of Bowers' patents on the grounds of anticipation, abandonment and various other grounds relating to acts both of the inventor and of the Patent Office. He questioned the authenticity of the drawings of 1864, claiming them to have been made twenty years later and antedated. He denied that it required the exercise of "invention"

to produce the devices of Bowers from the prior state of the art. He contended that Bowers' devices never did, in fact, work on the "hydraulic principle," as that term is applied to modern dredgers, but that they were constructed upon the principle illustrated in the early experiments with the "pressure column." He contended that the patents sued on should be construed literally and restricted to the exact construction shown and described, and that "inward delivery" should be construed to mean mechanical transportation of the severed material from the point of severance to the entrance of the suction pipe, unaided by atmospheric pressure.

In the San Francisco Bridge Company case, now awaiting decision, practically the same defences were made as in the Von Schmidt case, except that the authenticity of the drawings of 1864 was not called in question, and more emphasis was placed upon the "pressure column" theory in an endeavor to prove that "the law of the machine" in question is different from that of the patent; in other words, that the fundamental idea upon which each machine is based is different, and consequently the machines themselves must be different.

Much emphasis was also placed upon the Schwartzkopff patent, introduced into this case as new evidence.

The decree in the Von Schmidt case is very broad, and the decision of the Circuit Court of Appeals is still more clear and comprehensive. Only a few short extracts can, however, be given.

After analyzing the prior state of the art, the decision goes on to say: "But prior to the complainant coming into the field there was no machine, by whatever name known, that would, by the simultaneous and continuous co-operation of its various elements, cut and remove hard material from a waterway, and itself transport the same to any desired distance and place." Referring to the drawings of July, 1864, the decision continues: "Counsel for the appellant assert in argument that this date is false; that the drawing was actually made in 1884 and antedated twenty years. . . . There is nothing in the circumstance relied upon by the appellant to cast any doubt upon the testimony of the complainant in respect to the drawings, especially as there is much corroborative testimony. . . . We are satisfied from the evidence that they, together with the memorandum appearing upon them, were made at the time they respectively bear date. . . . They show not only an altogether new combination of elements for the transportation of spoils, but also something radically new in rotary excavators, namely: a rotary excavator with inward delivery

through itself, in combination with a suction pipe. They show a dredge-boat having two self-contained pivots or centers of oscillation for swinging of the boat while at work; a flexible joint near the pivots; a discharge pipe consisting of an inner flexible oscillating section composed of a series of sections flexibly joined together and supported by floats; and an outer rigid non-oscillating section, a suction pipe, a rotary excavator having inward delivery, the arc-shaped cuts of the excavator made by the dredge while swinging from side to side on the pivot, and devices for working with a side feed." Referring to the delays in connection with the patents, the decree continues: "It is enough to say that, so far from showing any intentional abandonment, they show the most persistent and continuous effort on his part against very adverse circumstances to perfect and avail himself of its benefits."

Referring to the experimental machine, the decision says: "The fact, if it be a fact, that the first machine built by complainant, called in the records the Davis machine, was not successful in its operations, is unimportant. . . . It would be certainly a novel doctrine to deny to an inventor the fruits of a broad invention because the machine which first embodied it was rudimentary in character and failed to do as good work as improved machines made subsequently. None of the great inventors could survive such a test. . . . He is, therefore, justly entitled to be regarded as standing at the head of the art of hydraulic dredging."

This story of the growth of a machine can hardly be other than what it is intended to be—a prosaic statement of facts and dates from sworn testimony of court records and personal observation. A few readers, here and there, can, like the writer, fill in the blank of years so lightly passed by in narration. To these this story will present another and entirely different aspect, one which thrills with human feeling and sympathy; a story of trial, disappointment and hope deferred; of ill-health and reproach; of high hopes and ambitions; of youth and manhood worn away as slowly, but surely, as dropping water wears stone by the passing days of passing years. These will know that progress as well as religion demands its martyrs, and that success, so dazzling to the beholder, is but a lightning flash on a summer evening, incapable of dissipating the chill of a life's journey in the valley of shadows.

DISCUSSION.

Prof. Soule.—I would like to ask Mr. Bowers about the dredger that was built and attempted to be operated in Oakland. I think it was about 1870 or 1874. I think a man by the name

of Ball was the inventor. As I understand, it did not prove successful.

Mr. A. B. Bowers.—I am thoroughly familiar with the dredge referred to. It was not a suction dredge, but had an endless chain of buckets, from which the spoil was dumped into a chute and discharged into a scow alongside. Later on, about 1880, he got up a dredge for A. E. Davis, in which the chain of buckets dumped into an elevated hopper, into which a stream of water was pumped, and the spoil and water descended by gravity through an inclined pipe into and through a short length of horizontal pipe. The mud, mixed with water, was carried through a short length of discharge pipe with considerable facility, in spite of its greater specific gravity, but when the inventor came to add any considerable length to his discharge pipe he met with difficulty in transporting the material. He was at work at Alameda Point for several weeks, but did not succeed in satisfying Mr. Davis, the owner of the machine, who soon after dismantled it.

Mr. Grunsky.—A dredging machine, possibly the same that has been referred to as the "Williams & Bixler," was at work in 1878 in the San Joaquin river. The material handled was principally sand. It was pumped up from the bottom of the river and deposited on shore through a suspended pipe. I noticed on the dredge an assortment of variously-shaped hoods that had been tried for the purpose of compelling the water—in flowing around the edges of the hood-shaped pipe-end—to take up the sand. I have only an imperfect recollection of the machine, which I did not carefully examine. Perhaps Mr. Bowers can give some additional information about this machine. I believe it was called the "Von Schmidt" at that time, but from the description given in the paper this evening I infer it might have been the "Williams & Bixler."

Mr. Bowers.—That was the first Von Schmidt machine. It was built for Williams & Bixler in the fall or winter of 1876. The suction pipe had an outer vertical telescoping section provided with a flared mouth or hood, about eight feet in diameter, within which was a rotary propeller-shaped agitator designed for an excavator. The diameter of this agitator was considerably less than that of the hood, but it depended some three or four inches below the hood. This agitator was unable to cut hard material, but if it had succeeded in boring a hole of its own diameter, or a little larger, by lowering it and the hood, it could go no deeper than its projection below the hood, because the greater diameter of the hood would cause it to rest on the uncut material around

the hole made by the agitator or excavator, and this propeller-shaped device projected so slightly below the hood that it would not have been practicable to work it with a side feed or swing, even had it otherwise been capable of so working, because, in order to do this, the bottom would have had to be perfectly level, parallel with the surface of the water. If the propeller was swung sidewise it would take off nothing but a thin shaving from the bottom. And, even if the bottom had been perfectly smooth and level, the propeller blades had not sufficient excavating capacity to make the device practical, while in soft material and loose sand it was discarded as useless.

The owners of that machine, finding that it would not answer their purposes except for pumping sand, had it remodeled, as stated by Mr. Smyth, into what was known as the first "Atlas" dredge, a prototype of the dredge now used by the San Francisco Bridge Company and the New York Dredging Company. It is almost exactly the same, though a few small changes have been made in the details. This was the first dredge of the "Atlas" type ever constructed, and was built at the Golden State and Miners Iron Works.

Prof. Soule.—I believe that hydraulic dredging has recently been carried on upon a very large scale on the Mississippi river, in relation to levee work there.

Mr. Grunsky.—I think chiefly in regard to deepening the channel and cutting through bars. The object is to keep open a narrow, deep channel during the low-water season.

Prof. Soule.—I have been told that a great deal of matter is handled, and that the power of the pumping engines has been greatly increased, so as to throw the water through the pipe at a much higher velocity than formerly, and that by doing this a much larger percentage of material is secured with the water—I think as high as 50, or even a greater percentage.

Mr. Smyth.—In some hydraulic dredging operations samples of the discharge ranged as high as 70 per cent. in solid material. It is doubtless desirable to have a high velocity in the carrying stream. The higher the velocity the greater, of course, is its burden-carrying capacity; but as water, traveling six inches per second, will move sand, and as the speed of flow, in ordinary dredging operations, is about fifteen feet per second, it would seem that this velocity would carry about all that could be excavated. The difficulty met with usually lies, I think, in the construction of the excavator, and particularly in the fact that the suction opening is not brought sufficiently close to the bank.

The suction pipe is frequently placed centrally in the excavator, and the material has, consequently, to be raised through considerable distance. In this form of construction the velocity of the stream, at the circumference of the excavator, in the bank where the cutting is done, is very much less than at the mouth of the suction pipe. This matter does not appear to have received the consideration due to its importance. In the San Francisco Bridge Company's construction something has been done in this direction by entering the suction pipe in the lower segment of the excavator and opening it downward, thus bringing its mouth nearer the point of excavating operations, and the excavated material more nearly within the influence of the inrushing current at its point of greatest intensity.

Mr. Bowers.—I have given considerable thought to the construction of excavators for hydraulic dredgers. I have designed many different forms, and have carefully noted the performance of others. In nearly all excavators having an inward delivery spoil finds its way to the mouth of the suction pipe with sufficient facility, except in very hard or in very sticky material, for each of which special and very different provision should be made. There are advantages and disadvantages with both concentric and eccentric suction pipes, considered in relation to the excavator, but in most cases either, when properly handled, is sufficiently efficient to furnish the pump with all the spoil it can force through the discharge pipe.

Mr. Grunsky.—I might add that the dredgers used on the Mississippi are of very large capacity. The largest have six suction pipes supplying two large centrifugal pumps. Three suction pipes deliver into each pump. These pumps send the material and the water through a discharge pipe that trails behind. The material is generally sent down stream 2000 feet or more and deposited in some deeper spot in the river channel. The material is not used for building levees. The channels cut through bars are only intended to benefit low-water navigation temporarily. I am told that the latest experiments have been to determine the efficiency of water jets used as a substitute for the rotary cutter in severing material. I do not know what the results have been.

Mr. Smyth.—In my previous remarks I suggested that lack of efficiency was not due to lack of speed of the current. This is borne out by the fact that in many excavators, and notably in those of the San Francisco Bridge Company, they bring up large boulders; in fact, I saw in court one day a cannon ball, eight inches in diameter, which had been raised by the suction pipe. Mr.

Bowers' dredgers have raised stones of that size. It is not the speed of the water that is deficient. That ordinarily employed is sufficient to carry the material usually dredged.

Mr. Henny.—I would ask the author of the paper if he can give us some information upon the comparative cost of dredging with clam-shell dredges, with endless chain buckets and with this new method of dredging. I realize the fact that the cost is a very variable quantity, and I have in mind some instances where the different methods of dredging have been used for the same piece of work.

Mr. Smyth.—Mr. Bowers could give fuller and more accurate information, his opportunities of making the comparison desired having been much greater than mine.

Mr. Bowers.—There are circumstances under which dredging can be better done with an old Osgood scoop than with any other machine. Work of that character, in very hard material, will cost, with the scoop, from 30 cents to $1.50 a yard. Such material, under favorable conditions, can be handled with a hydraulic dredge for from 30 to 60 cents, if the discharge pipe is short and the lift is low. All of these things have to be taken into consideration. You can handle a very large percentage of sand or gravel through a short pipe with a low lift, and do it without great expense other than that of the wear and tear of the machine, which is excessive in sharp gravel.

There is other material to be taken up and deposited 50 to 75 feet alongside from where it is found, and such can be handled more cheaply with a long-boom clam-shell than with any other device that has ever been employed. This machine is particularly well adapted to the building of levees, where the material is within reach of the boom, and where the boom can carry it to its proper place in the levee. Soft, semi-liquid material cannot be taken up with any considerable advantage by either of these machines, or by the endless chain bucket. The passage of loaded buckets through the water will wash out such material, and the jaws of the clam-shell are seldom close fitting, but are usually separated sufficiently to allow sand and soft and semi-liquid material to escape in considerable quantities. A very considerable percentage of such material is lost by leakage, as well as by being washed out, as it is raised through the water. For this class of work hydraulic dredgers are vastly preferable under suitable conditions, as well as for the excavation and transportation of most material where the point of discharge is not too distant and at too great an elevation. In such cases hydraulic dredgers are efficient and econom-

ical. In the handling of sedimentary deposits, and even clay and compact sand, the cost, with the hydraulic process, is probably less than one-half the cost by any other method where the material has to be put on shore within a reasonable distance, but beyond the reach of the ordinary machines.

The last contract given by the United States Government for dredging with a clam-shell between the Oakland jetties was taken by Mr. John Hackett, and the price he received for it was 34 cents a cubic yard. He was required to take the material out of the channel and deposit it on shore. He put it into scows and towed it to a wharf near the mouth of the Oakland creek, and there dumped it alongside the wharf. On the wharf he had another clam-shell dredge that took the material up again and put it into dirt cars furnished by the Southern Pacific Railroad Company, for which he was paid 4 cents a cubic yard, if my memory serves me rightly. The superintendent of the Southern Pacific Railroad Company told me that it cost the company 12 cents a cubic yard to transport the material, shovel it off the cars and spread it over the ground. They had to use shovels in unloading, because the mud was very sticky—a sort of clay. They first laid a temporary track and shoveled off the mud on each side, then took up the track and put it in another place close by, parallel with the first, and so continued that process, though after a time they discharged the material only on one side, and then moved the track back as the place was filled, in order to make clean work as they went along. This would be, then, 34 cents for dredging and towing, 4 cents for taking the material up again and putting it into cars and 12 cents for transporting on cars and unloading, making a total of 50 cents per cubic yard for dredging the material in that way and transmitting and spreading it over the land. Hydraulic dredge contractors now think that if they get a large contract for doing such work at 15 cents a cubic yard they are doing fairly well, if the material is to be delivered at a low elevation through a short discharge pipe, with all other conditions favorable. The hydraulic dredge is a special tool for special work, and, in its own sphere, is without a rival. Having patented my dredge mainly for my own protection and use as a contractor, and for the protection of my licensees, it is obviously unwise for me to chant its praises too loudly or to set the cost of work at too low a figure.

The "Beta," used on the Mississippi river for cutting through sand bars, has six suction pipes and six cutters on one hull. It is equivalent to six dredgers in one, and when one is laid up for

repairs the whole plant is idle. It has been at work for several months, with a very heavy percentage of lost time. I am coming very near criticising it, which I do not now wish to do. I will say, however, that it does not handle six times as much material as has been handled by a single cutter, though the quantity is very large while actually working, and all the more so from the fact that it is lifted but slightly *above* the surface and is discharged *at* the surface of the water. The results obtained from the use of this dredge have not been such as to encourage its duplication, and others of different types have been built instead. If the discharge pipe is long and the end of the pipe is considerably raised, the amount of material that can be discharged diminishes very rapidly with the elevation; but if the mouth of the discharge pipe can be kept low, a very heavy percentage of earthen material can be delivered continuously. If the discharge pipe is not too long, a heavy percentage can be delivered at a fair elevation; but with a pipe that is a mile or a mile and a half long, and with a heavy elevation at the mouth, the amount that can be delivered dwindles very rapidly with the increase of elevation.

Prof. Soule.—In what order would you place the different soils or material that can be removed by a hydraulic dredger alone, leaving out the rocks and heavy boulder material?

Mr. Bowers.—I surmise that Professor Soule, the head of the College of Engineering of the University of California, could elucidate these questions, much to our edification. From my practical experience, however, I may state that silt and semi-liquid material require but little power to sever them from the mud bottom, and can be moved very cheaply and more rapidly and economically than any other. This was the character of the spoil handled by these machines on the Drainage Canal at Chicago, where, at times, there were moved, with a single hydraulic dredge, 10,000 or 12,000 cubic yards per day of such material. The dredgers used were of simple construction—almost make-shifts—for the sake of getting up as cheap an apparatus as possible, and it is astonishing that such results were obtained from inefficient machines. This was owing to the extreme softness and liquidity of the spoil.

Taking this material with constantly increasing hardness—such as is found in sedimentary deposits, up to pure clay (for a great deal of this semi-liquid material may solidify and form clay, in the course of time)—the expense constantly increases with the increasing hardness of the material. But hard clay is a better material to handle, if it is to be transported a long distance, than

even loose sand, for the friction of sand in long pipes is excessive. When you undertake to carry sand more than half or three-quarter of a mile the friction is so great and the tendency of the sand to deposit in the pipes is such that one is obliged frequently to cease excavating and wash out the sand by pumping clear water alone. This is the case with all kinds of sand if you attempt to discharge them through too long a pipe. Coarse gravel and cobblestones, owing to their weight and the centrifugal force of the pump, rapidly cut out the shell of the pump and also the pipes through which they pass.

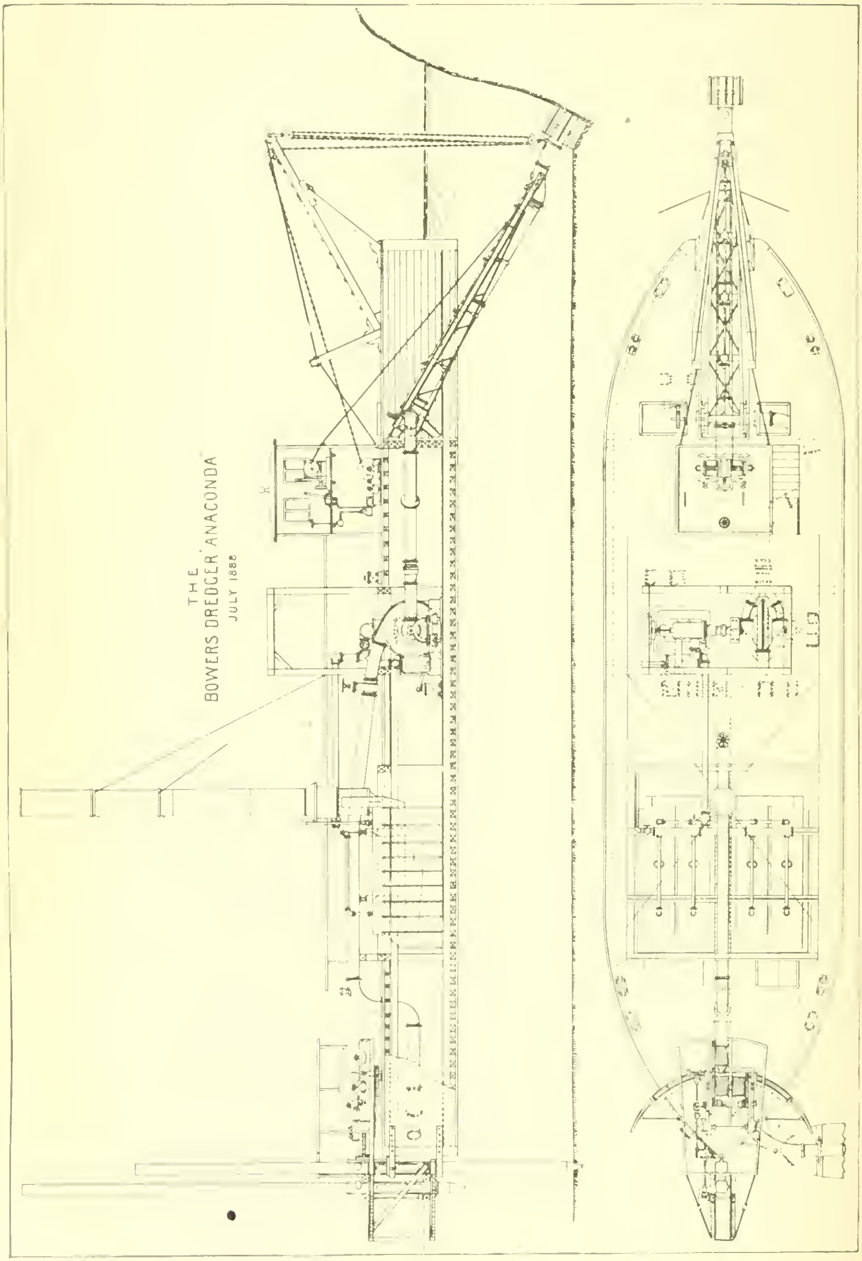
The Bowers dredge "Python," at Tacoma, took up coarse gravel, from the size of a pea up to 2 inches in diameter, with an occasional boulder as large as a man's head. This material was elevated about 30 feet and discharged through 1000 feet of pipe. But the company did not make money on the contract.

Prof. Soule.—The gentleman who gave me the information about dredging in the Mississippi river said that one great necessity for the high velocity was to prevent the sand from settling and trailing along the bottom of the pipe.

Mr. Grunsky.—Can any one tell me what the velocities in the delivery pipes of the Mississippi dredgers are? It attracted my attention as being in excess of that customary on this coast.

Mr. Bowers.—The flow of material in the discharge pipe of the Von Schmidt dredge, when I tested it, was about 11 feet per second. In my dredger it has run from 15 to 20 feet. The velocity in the San Francisco Bridge Company's discharge pipe is about 15 feet. It varies above and below. At the time I was on the Mississippi I witnessed some experiments with the "Beta." The velocity of the discharge was not tested at that time, but I thought, from the appearance at the end of the pipe, that it was not high. It did not seem so high as the speed I have given for the machines on this coast. This was prior to the official tests, and the speed may now be greater. It has been found, however, that a rapid stream in the discharge pipe is more advantageous, when handling sand or gravel, than a slow speed, but in handling sedimentary matter or semi-liquid, clayey or slippery material it is not so important, if only the pressure from the pump is sufficient to force the material through the pipe, even if the pipe is almost full of it.

Mr. Vischer.—I feel as though it was almost an imposition to ask Mr. Bowers for so much information, after what he has said, but as we know he has all these things at his fingers' ends, I would ask him to give us a few figures as to the size of his dredgers, and how much they handle.


THE
BOWERS DREDGER 'ANACONDA'
JULY 1888

Mr. Bowers.—The first dredge that I built, after the experimental apparatus which has been referred to this evening, was the "Anaconda." That was put into operation at Glorietta Bay, a bight in the Bay of San Diego. The material there was very hard, compact sand.. The dredge handled, in one run of 5 hours and 20 minutes, something over 3000 cubic yards. That was the first work of the first complete dredge that I built. It was a dredge of about 175 horse-power on the pump. That same dredge, after being taken to Tacoma, on Puget Sound, handled 165,000 cubic yards in 20 days, running continuously. The material was a sedimentary deposit, composed partly of sand and partly of clay. That, I believe, is the best record ever made. No other hydraulic dredge, with a single cutter and with the same power, has come up to this.

I constructed, for the Bowers Dredging Company, a second dredge of some 400 horse-power, and that is the one that handled the gravel and cobblestones to which I have just referred. It has not yet had an opportunity of showing what it would do under favorable circumstances. The dredgers on the Chicago Drainage Canal made no such continuous record as the "Anaconda," even in the semi-liquid material which they handled there, but for short spurts of one or two days they exceeded the average output of the "Anaconda" for these 20 days of which I have spoken. I think that the highest record they made at Chicago was a little over 100,000 cubic yards in a single month. I have the figures somewhere, but my recollection is that it was about that. It may, perhaps, have been a little higher, I am not quite sure.

The Von Schmidt dredgers at Washington, D. C., at work on the Potomac Flats, handled, in soft mud, something over 100,000 cubic yards a month. At one time they were working in sand and discharging a mixture of gravel and boulders through 1400 to 1700 feet of pipe. In this material they moved from 700 to 1200 cubic yards per day. It was frequently necessary, during the day, to raise the cutter and wash out the discharge pipe by pumping clear water. It would sometimes take two hours to clear the pipe of cobblestones, which, in passing through it, would frequently make a racket similar to that of a passing train of cars.

Mr. G. W. Dickie.—I had some experience in dredging machines as far back as 1860 and up to 1869, in connection with dredgers built by Siemens, on the Clyde. These, as you know, were the standard type of chain bucket dredgers. I am not sure whether any of the suction types of dredging machines, on a general proposition, will equal the old chain bucket dredger. There

are places where the pump dredger will do better, and certain kinds of material which it will lift and deposit cheaper, if the distance is not too great. I have in mind a dredger that was used by a railway company in England for years, and it never was laid up but a day or two at a time for repairs. It would dredge 3000 tons of material a day, mostly of stiff clay—so stiff that when it fell out of the bucket it would keep its shape. A good deal of it was moved about two miles, and the average cost was a little less than 3 pence, or 6 cents, per cubic yard. I have not heard to-night that any dredging has been done here as cheaply as that, even in easily handled material.

When we were preparing for the dry dock at the Union Iron Works the San Francisco Bridge Company had the contract for dredging. If I remember correctly, we paid them 15 cents a cubic yard. As a matter of curiosity, I kept the time of all the hands employed, the amount of coal burned and of other supplies, as near as I could, and the actual cost was between 9 and 10 cents a cubic yard. This shows that the method of dredging was not very cheap. Sometimes the amount of material, as compared with the amount of water pumped, was not very great; at other times it was up to, I should say, 60 per cent., and again it went down, probably to not over 20 per cent., and especially when the machine was taking the material below 30 feet and the ground got a little hard.

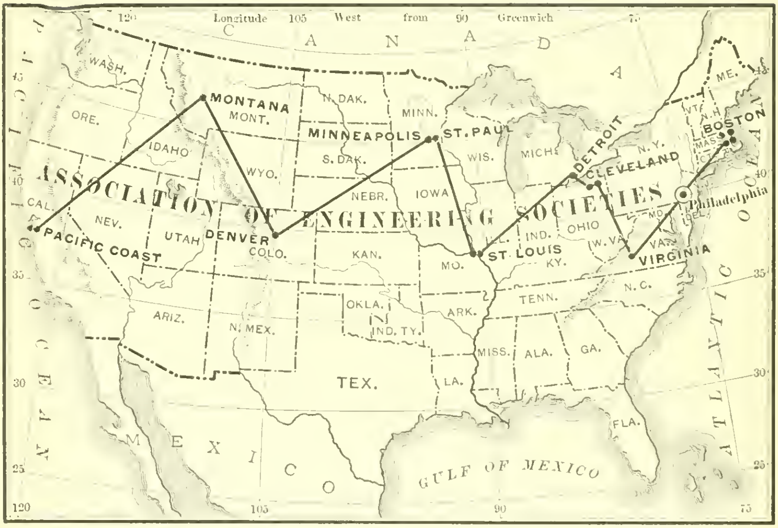
A large proportion of the dredging that will have to be done in the harbors of this country, I think, will follow the course that has been pursued in Europe; that is, to carry the material a long way. Here we deposit the material a few hundred yards from the water front, and it is not long before it comes back again. Where it is not convenient to deposit on shore, the material should be carried out and dumped beyond the ocean bar.

The pump dredger will have quite a field of operation under circumstances which favor that kind of dredging, but I am sure that a very large proportion of dredging will not admit of it, simply for want of a convenient place to put the material. It can be used only where the material can be deposited within certain distances from the excavation.

R. H. Postlethwaite.—I came here recently from New Zealand, where a great deal of dredging for gold has been done. It commenced thirty-odd years ago. It started with the old spoon dredge, which now has developed into the dipper dredge. It was originally worked by hand power, after which a current wheel was used, having continuous buckets, similar to those used now;

but this could be used only for dredging in the current of the river, and could not touch the banks, where there is a large quantity of good gold-bearing dirt. Therefore, this style of dredger had a very limited field of operation. After that came the bucket dredge, with an engine on board, run by steam, so that it might work anywhere. I think we have over 100 of these dredgers running in New Zealand.

To handle dirt for our purposes successfully and cheaply, we must have a machine that will work continuously. Especially in the saving of gold do we want a regular, continuous stream. The dredgers we are using will not only lift heavy material like gravel, but also stones and boulders, from 200 pounds to a ton in weight. I think you will find a very large field for dredging in this state when I tell you that for years in New Zealand we have operated dredges in heavy material, lifting it from 45 to 50 feet above the surface of the water. Lifting it from 20 to 30 feet has cost less than 5 cents a cubic yard. We reckon there that anything over 3 cents a cubic yard will pay expenses, and there are dozens of dredgers now which are working dirt that is not paying more than that, while those averaging 5 cents a cubic yard are paying handsomely. In removing sand we might be able to use the suction dredge more successfully. Every dredge must be built to suit the conditions in which it is to be used.



BRADLEY & POATES, ENGR'S N.Y.

Association
of
Engineering Societies.

Organized 1881.

Vol. XIX. NOVEMBER, 1897. No. 5.

PIPE LINE NO. 2 AND THE LANDS IRRIGATED UNDER IT AT CORONA, RIVERSIDE CO., CAL.

By H. Clay Kellogg, Member of the Technical Society of the Pacific Coast.

[Read before the Society, November 5, 1897.*]

Corona, formerly known as South Riverside Colony, is situated on a mesa about three miles in width and six miles in length, on the northeastern slope of the Santa Ana Mountains, with a fall of 150 feet to the mile. The colony was laid out in 1886–7, and the first pipe line was completed in July, 1887. To-day the town and colony has a population of about 2000 inhabitants, and there are 7000 acres planted to orchards, mostly oranges and lemons.

The water supply, which is taken from the Temescal Cañon, has for the most part been developed, as there were only about fifty miners inches in sight in the beginning. These developments have been made by running submerged drains, building reservoirs and boring artesian wells. Lake Elsinore has also been secured as a reserve supply.

The increased demand for land caused investigations to be made looking to the construction of a higher pipe line to irrigate the choice lands above the line already built. This led to the construction of pipe line No. 2, the subject of this article. This line has a capacity of 400 inches, and is 150 feet in elevation above pipe line No. 1, taking in an additional area of 2000 acres.

* Manuscript received November 15, 1897.—Secretary, Ass'n of Eng. Socs.

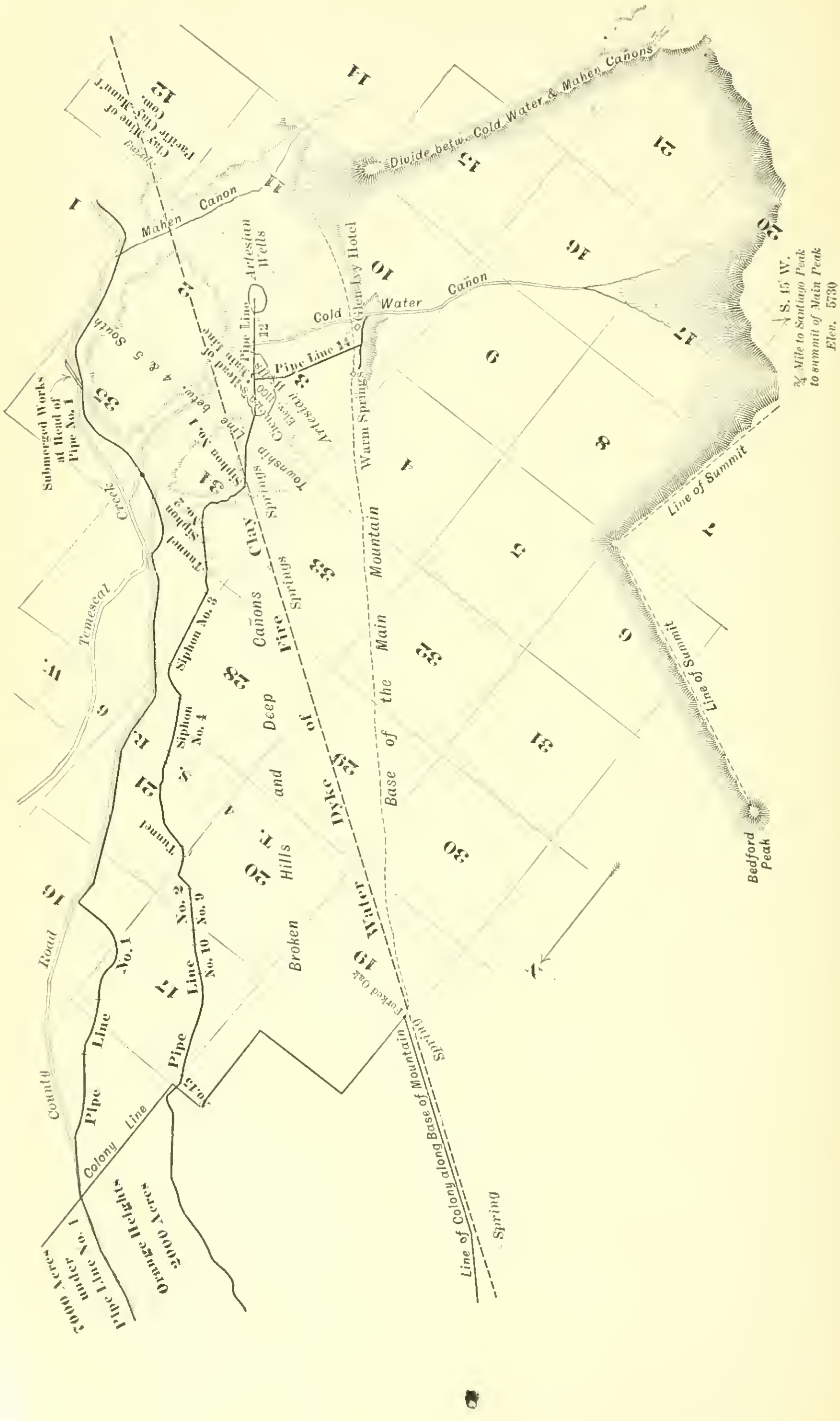


Fig. 1. Plan of South Riverside Colony.

SOURCE OF SUPPLY.

Pipe line No. 2 is supplied by artesian wells and by a mountain stream, known as Cold Water Cañon. The supply from this stream is about 125 inches in winter and 25 inches in summer, leaving the major portion to be supplied by the wells. These wells are situated in a basin at the mouth of Cold Water Cañon. This basin is caused by a dike of fire clay which runs almost parallel to the mountain range, course N., 58° W. I regard this dike as the most important natural feature in our water supply. I have traced it for about 15 miles by the outcroppings, where large washes from the mountains intersect it, and by springs which appear all along the line. In the driest season of the year the mountain gorges are dry, except where they intersect this dike, and the peculiar feature of this is that living springs are found only along this dike. This is forcibly illustrated by a spring on top of the mountain, at the northwest end, where the dike intersects it. My theory is that the subterranean flow from the northeastern slope of the Santa Ana or Temescal range is intercepted by this dike, and that at the basin mentioned, where the artesian wells are located, the dike is farther from the mountains, making this the largest part of the subterranean reservoir. It is also opposite the highest peaks of the range, which are drained by Cold Water Cañon. I have no maps that definitely give the area of the watershed. The elevation of the highest peak is 5730 feet, and the elevation at the wells about 1100 feet.

The wells are 13 in number, and vary from 130 to 260 feet in depth, the best flows being obtained at 130 and 165 feet in depth. These wells, if capped during the winter months, will supply about 300 inches of water, and they have thus far been adequate to the demand.

PIPE LINE NO. 2.

The total length of the line is 30,093 feet, from the wells to the intersection of the lands that are irrigated. It is located over the most irregular and broken country I have seen where water has been conducted, lying parallel to a precipitous mountain and intercepting the mountain washes at right angles. In locating the line, two objects had to be kept in view, namely: to secure economy of construction, and to take in all the land possible. There were four heavy ridges to cross, and, to avoid long tunnels, a slight detour was made and more pressure pipe used. The pressure pipe was found to be cheaper, and it did not materially alter the elevation of the grade line at the terminus. Having our

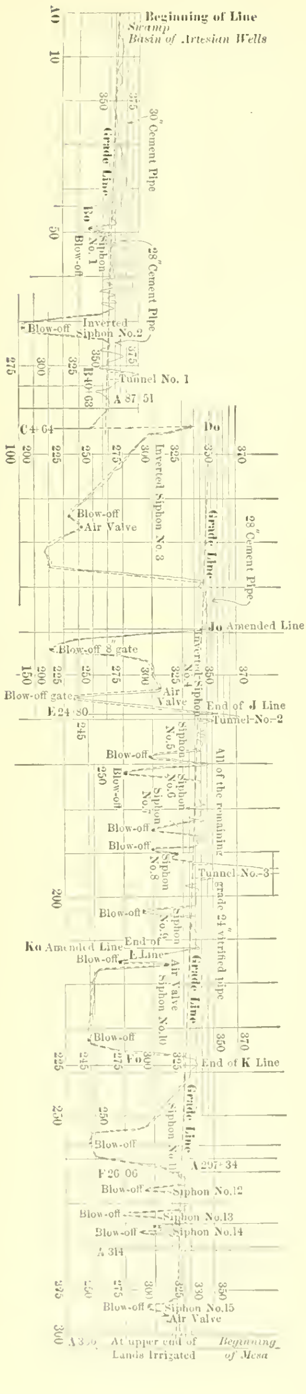


FIG. 2. PROFILE OF PIPE LINE NO. 2.

capacity fixed at 400 miner's inches, I established the hydraulic grade at 4 feet to the mile for 28-inch pipe and 7 feet to the mile for 24-inch vitrified pipe and for all 24-inch steel pipe used in inverted siphons. In the construction we put in 30-inch pipe for the first 4437 feet on a grade of 3.2 feet to the mile, 5267 feet of 28-inch pipe on a grade of 4 feet to the mile, 6237 feet of 24-inch vitrified pipe on a grade of 7 feet to the mile, and 14,125.1 feet of 24-inch double-riveted steel pipe, which was distributed throughout the line in 15 inverted siphons across the canons and washes.

CEMENT PIPE.

The cement pipe was made of three and one-half parts of clean, sharp bar sand to one of cement, and the mortar used for laying was made of two parts fine, sharp sand to one of cement. The pipe was made within a mile of the line, in Temescal creek, where the very best quality of sand and gravel can be found in large quantities. The vitrified pipe was made at the Pacific Clay Manufacturing Company's Works, which are located at Corona. The pipe used was a good quality of salt-glazed pipe.

DITCH.

The ditch to receive the pipe was made 3 feet wide on the bottom, with side slope of $\frac{1}{2}$ to 1 foot. The material was a muck for the first half-mile, at the upper end in the well basin, hard gravelly clay and hard pan on the ridges and loose rock and boulders across the washes.

There were three tunnels, each about 300 feet in length, through tough clay and soapstone. They required no timbering. All the work was done by contract, and, while the specifications and advertisements were made to divide the work up into small sections, all the work was contracted to one party, except the steel pipe, which was made a separate contract.

CONTRACT PRICES.

Common earth, 13½ cents per yard.
Ditch work, hard pan, 46 cents per yard.
30-inch cement pipe, laid in ditch, $1.16 per lineal foot.
28-inch cement pipe, laid in ditch, $1.09 per lineal foot.
24-inch vitrified pipe, laid in ditch, $1.20 per lineal foot.
Manholes, $3.00 each.
Bell holes, $1.50 each.

STEEL PRESSURE PIPE.

All pipe under a head of 65 feet or less was No. 14 Birmingham gauge, weight not less than 3.12 pounds to the foot, and all pipe under a head greater than 65 feet was No. 12 Birmingham gauge, weight not less than 4.3 pounds to the foot. All pipe laid with a head of 30 feet or less was laid with a driven joint. All pipe laid under a head greater than 30 feet was riveted together in the trench. The pipe was in lengths of from 21 to 24 feet. All pipe was coated with J. D. Hooker's asphalt coating. An 8-inch blow-off gate was put in at the lowest point of each siphon, and an air-valve where the pipe crossed a ridge between two low points. This occurred in only three instances in the entire line.

PRICES PER LINEAL FOOT.

No. 14, 24-inch double-riveted steel pipe, laid in trench with driven joints, $1.39.

No. 14, 24-inch double-riveted steel pipe, laid in trench with riveted joints, $1.58.

No. 12, 24-inch double-riveted steel pipe, laid in trench with riveted joints, $1.96.5.

Angles and curves, three times the price per foot of the pipe used.

Blow-off gates, $45.00 each; air valves, $18.00 each.

This made the total cost of steel pipe, $25,479.15.

The contracts were signed on January 7, 1892. The work was to be completed by April 10 of the same year. It was practically finished on May 1.

CONSTRUCTION.

F. M. French, of Los Angeles, was the contractor for all the work, except steel pipe, which was made and put in by J. D. Hooker, of Los Angeles.

The contract for the cement and vitrified pipe was sublet to the Pacific Clay Manufacturing Company, a large portion of the vitrified pipe being already made at the factory. Within two weeks 200 feet of cement pipe was being made per day, while a large force of men and teams was opening up the ditch. The entire work was pushed with the same characteristic vigor until completed, with scarcely a hitch anywhere. Many difficulties were encountered, but they were generally provided for in advance, and expensive experiments with large forces were avoided.

The only part of the line that gave us any serious annoyance was the first 1800 feet leading out of the well basin. This was in a black muck full of water, and the bottom of the ditch was so soft that it would not bear the weight of a man. The ditch averaged about 4 feet in depth and 4 feet wide on the bottom, but when I went to inspect it, prior to laying the pipe, about a month after it was dug, I found it closed in to 2 feet in width in many places. We then considered the question of changing the structure at this point to a flume, but, as a flume had not proved very satisfactory in a similar case, we decided to experiment with the pipe, as it was already on the ground. And near at hand there was an abundance of willows, from 3 to 4 inches in diameter. I had these cut into 4-foot lengths and placed crosswise of the ditch, as close as they could be laid, and then placed two 1″ by 6″ boards lengthwise, about 10 inches apart, on top of the willows. To our surprise, we found that the cement pipe, which weighed about 130 pounds to the foot, could be laid on this foundation without difficulty. As soon as the pipe was laid, I had sand and gravel tamped in on the sides to a depth of 14 inches, using about 1 cubic yard to every 4 lineal feet. This may seem to be a reckless expedient, but the pipe has not settled or given us any trouble since, and it has been in use five years. On all grade pipe manholes were placed at intervals of 300 feet, and, in addition, a manhole was placed within 15 feet of each end of each inverted siphon. On the cement pipe these manholes were made by cutting a hole with a cold chisel in the top of the pipe, and cementing on vertically a joint of pipe 2 feet in length, or a sufficient number of joints to bring the top of the standpipe above the surface of the ground. For the vitrified pipe a special joint was made with an 18-inch opening on the side, to which the pipe was attached vertically, as before. Subsequently I had wooden covers made and bolted on the tops of these standpipes with from six to eight ⅜-inch holes for air vents.

The connections with the steel pipe were made by extending

the cement pipe about 18 inches over the end of the steel pipe. After carefully caulking the seam, a masonry pier, 18 inches in thickness and 4 feet in length, was placed around this connection. On a connection with vitrified pipe a joint of the 28-inch cement pipe was supplied.

TUNNELS.

The tunnels were made 4 feet wide on the bottom and about $5\frac{1}{2}$ feet high. They were lined with 28-inch cement pipe and back-filled with sand to the top of the pipe. The rest of the space was filled with the material excavated.

ENGINEERING.

The writer himself established the center line prior to the commencement of the work, and made out a table showing the station, course, elevation and grade. The additional data for a working section were afterward supplied. The slope stakes were set immediately in advance of the graders by the writer's assistant in charge of the grading. In this connection it will be in order to state that, two years before, a careful preliminary survey was made, with a complete estimate of cost, and the contracts were let on this estimate, subject to any changes or corrections the writer might make during the progress of the work. During the progress of the work he had five assistants. One set the slope stakes, ran all the levels for finishing grades and looked after the graders. Another assistant, who was an engineer, looked after each gang of pipe-layers. There were three gangs laying vitrified and cement pipe and one gang laying steel pipe. These assistants were to inspect every joint of pipe as it was laid, rejecting all imperfect pipe; also, to see that the mortar was mixed in accordance with the specifications, and to see that each joint was properly lined in the trench. They kept a record of the work done, carefully noting any special features. This record was turned over to the writer every time he passed over the line, and if any question arose as to the quality of pipe or character of work done, it was left for his inspection. The assistants were given no authority to finally accept or reject any of the work, a provision of the specifications which proved very valuable, as it made the contractor more careful. The writer went over the work at least twice a week, and in three instances had work taken out after it was supposed to be finished. He crawled through all the grade pipe and inspected it with a torch after it was finished. To some this may seem extreme caution, or lack of confidence in the assistants, but it is believed that the cause of failure in many works of

this kind is the result of carelessness in the details of construction rather than in the specifications, and that success depends upon the thorough completion of every part.

There were instances where imperfect joints were made, that had escaped the notice of the inspectors. One of the greatest advantages of this inspection was, that it made all parties attentive and extremely careful in their work.

The water was run through the line before the work was accepted, and final payment was made 30 days afterward.

COST.

The amount paid for digging ditch, laying cement and vitrified pipe and backfilling the entire line was	$29,085.00
Amount paid for steel pipe	25,479.15
Total construction	$54,564.15
Engineering superintendence, including chief engineer	3,895.00
Preliminary survey	800.00
Total	$59,259.15

DISTRIBUTING MAIN.

The distributing main across the mesa will be, when completed, about 6 miles in length. The first 10,239 feet is of 28-inch cement pipe, the second 10,000 feet 24-inch vitrified pipe and the remainder 18-inch pipe. The 28-inch pipe and 2000 feet of the 24-inch pipe were put in at the same time as the main line (1892), at a cost of $1.33 per foot, complete. The remainder of the 24-inch pipe was put in in 1894–6. The line is located on a grade contour with a fall of 3 feet to the mile, the contour of the ground being followed, so that the cut at any point is not less than 2 feet or more than 4 feet. An avenue 80 feet wide was located, so that there is a 70-foot street on the lower side, which makes it possible to irrigate the upper side of the first lots. At all points where distributing laterals were taken out, a box, 3 feet square on the inside, was placed on the main line, the bottom of the box and the outlet pipe being placed 6 inches below the main pipe. These boxes were made of concrete (1 part cement to 7 parts sand and gravel, plastered on the inside with a mortar of 1 to 1). Cast iron gates were cemented into the side of the box at the end of the laterals. This construction has proved very satisfactory. The cost was about $8 for each box.

Before describing the distributing system, it will be necessary to describe the method of subdividing the land under this system. The method is unique, but as it has fully come up to all expectations, and, in practice, has successfully met all the criticisms that

were offered, the writer has no hesitancy in placing it before the Society as the best method to be used where the land slopes uniformly in two directions. As already stated, these lands had a slope of 150 feet to the northeast. In addition to this, they were slightly undulating at right angles to the slope, so that it was not always certain that the water would run at right angles in one direction from a lateral pipe running down this slope, and, even if it did, there would have to be a lateral for each tier of lots. As these laterals cost about $2500 per mile, it was suggested that a subdivision be devised in which one lateral would accommodate two rows of lots. It was found that by this means between $8000 and $10,000 could be saved in the cost of laterals on this tract. The following plan of subdividing was devised:

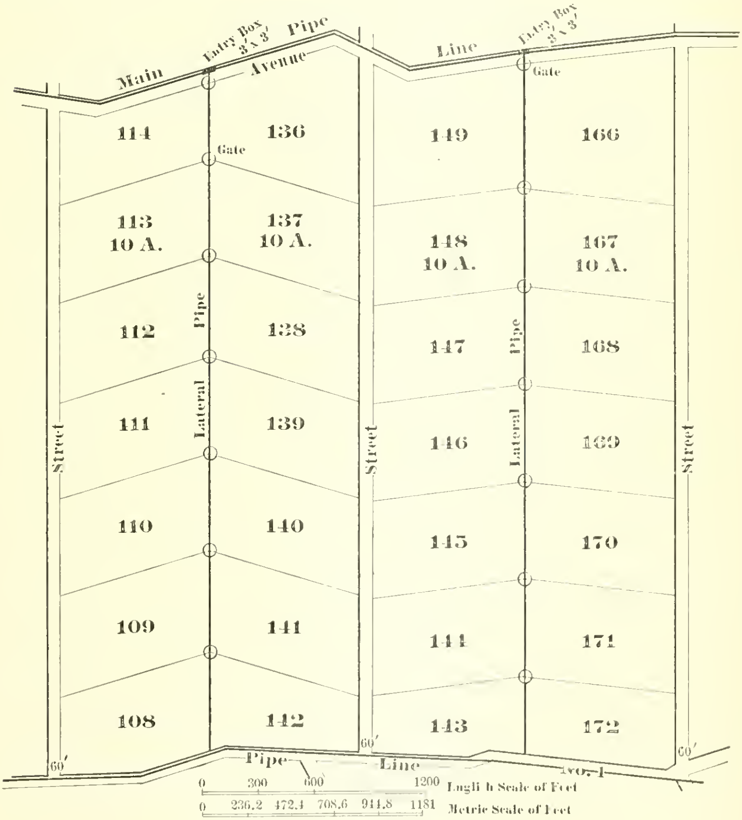


Fig. 3. Plan of Subdivision.

The street and lateral lines of pipe were placed as nearly as possible at right angles to the main line, and the corners of the

lots were moved up the slope along the laterals, so as to insure a fall of not less than 18 inches along the upper line of each lot. Contour lines were run, and the lines established on each block, in accordance with the slope of the ground.

As is usual with all new departures of this kind, many objections were offered. As the tract was to be set out to trees, it was claimed that the lots should be square, but it was easily shown that the rows would be just as straight in parallelograms. As a result, these lots have commanded the highest prices, as they furnish more opportunity for the exercise of taste in their improvement. More than half of the tract is now planted, there are many bearing orchards, and their appearance is a sufficient commendation of the plan.

The distributing laterals are made of 7 and 8-inch vitrified pipe, laid about 2 feet below the surface. The outlet gates, at the upper side of the lots, were made by building square brick boxes in the line, extending 15 inches above the surface and having flumes attached to each side. These are called head flumes. They extend along the upper side of the lots. They are made of wood, cement and vitrified clay, and they vary in size from 8 to 12 inches square, to correspond with the grade. I prefer the cement flume, which costs about 18 cents per lineal foot. The sides are 4 inches and the bottom 2 inches in thickness. About every 6 feet outlets were made, from which the water runs down small furrows, requiring about 10 to 12 hours to cross a lot 528 feet wide. The water is turned out of the lateral by a cast iron gate cemented into the lower side of the outlet box. The usual irrigating head is 25 miner's inches, equal to $\frac{1}{2}$ cubic foot per second. Young orchards are irrigated every 30 days, during the summer; older orchards about once every 6 weeks. The equivalent of from $2\frac{1}{2}$ to 3 inches depth of water is put on at each irrigation.

Paint Tests.

Discussion by Mr. W. J. Wilgus of Paper by Mr. Max Toltz.*

[Read before the Civil Engineers' Society of St. Paul, November 1, 1897.†]

As the results of my own experiments and observations differ somewhat from those of Mr. Toltz, I deem that the following remarks may be appropriate:

Mr. Toltz's recommendations, briefly stated, are as follows:

1st. Priming coat of linseed oil.

2d. Coat of asphaltic varnish.

3d. Coat of graphite paint.

The use of a priming coat of linseed oil is discountenanced by many engineers as tending to act as a "catch-all" for grit, dirt, etc., which are embalmed in the oil as it hardens, and are never perfectly removed. There is, however, the more serious objection pointed out by Mr. J. Spenrath, in his prize essay on "Protective Coverings for Iron," published in the *Railroad Car Journal*, that linseed oil, without a pigment, never thoroughly hardens, and ultimately blisters the succeeding coatings of paint. In the writer's opinion, the preferable method is to enforce rigidly that clause in our specifications which provides that the surface of the steel shall be thoroughly cleaned by the sand blast or other approved method before the application of the priming coats at the shop, even if the manufacturer must be paid an additional price for so doing.

The use of asphaltic varnish for the first coat of paint is, from my observation, inferior to that of a heavy coat of red lead and oil applied to a clean, dry surface. The assertion of Mr. Toltz that many progressive engineers are discarding the use of red lead is, I consider, unsupported by facts. Mr. Walter Berg, Principal Assistant Engineer Lehigh Valley Railroad, has made a careful, exhaustive, and intelligent research into the merits of various paints for railroad bridges, and, in an article published about a year ago, he states that replies to inquiries as to the prevailing practice on about 30 prominent railways show that over 80 per cent. recommended using red lead and oil for priming coats. Moreover, as a result of his extensive study of the problem, he endorses that practice. Spenrath holds that the sole weakness of red lead lies in its being attacked by hydric-sulphide, but with a

* Printed in Journal of June, 1897, vol. xviii, No. 6.

†Manuscript received November 20, 1897.—Secretary, Ass'n of Eng. Socs.

suitable second and third coat of paint this objection is of little paints, and submerging them for two weeks in water containing weight. Neither does Mr. Toltz produce any evidence supporting his adverse opinion of red lead and oil.

At the last annual meeting of the Master Car and Locomotive Painters' Association the preponderance of evidence submitted by various members went to prove that red lead and oil, as a protective coating for the metal parts of cars and trucks, is unsurpassed. Mr. Toltz remarks that the fact that advocates of red lead and oil had begun to add carbon black and graphite to their paint is a sure indication of their own disbelief in red lead alone as the best pigment. This remark seems to have as much weight as the one to the effect that the engineer using salt for mixing mortar in freezing weather really doubts the value of cement as a binding material. Lampblack and graphite are often used with red lead and oil, not necessarily to improve the lasting qualities of the pigment, but to make the paint work smoothly and evenly. Their use certainly in no way reflects upon the basic material as a preservative.

The experiments and examinations of various paints, in actual use by the writer, confirm the above conclusions. Tests made by covering clean, bright steel plates with two coats of 12 different one-half ounce of hydrochloric acid to one gallon of water, disclosed the fact that the relative merits of the paints thus tested were as follows:

1st. Red lead and linseed oil.

2d. Asphaltic varnish (pure, genuine) paints.

3d. Carbonizing paints.

4th. Graphite paints.

5th. Iron oxide paints.

6th. Cheap patent paints.

These tests gave excellent comparative results, as they emphasized the value of the three cardinal virtues of a good paint:

(a) Good adhesion to the metal.

(b) Lack of porosity.

(c) Resistance to chemical and galvanic action.

The absence of any one of these three qualities, even if the other exist, will cause the paint to fail.

Observations of paint on many steel bridges confirm the conclusions above stated.

The color of red lead is of course objectionable, and for second and third coats the use of asphaltic varnish paint is to be recommended. During the past four years the majority of the new bridges on the Rome, Watertown and Ogdensburg Railroad,

which were originally coated with cheap patent paints, have been repainted with a paint prepared from a formula given by Dr. C. B. Dudley, as follows:

4 pounds of pure lampblack ground in raw linseed oil.

$\frac{7}{8}$ gallon genuine asphaltic varnish.

$\frac{1}{4}$ gallon pure, refined, boiled linseed oil.

$\frac{1}{4}$ gallon drying japan.

These ingredients were purchased and mixed by the railroad company, and cost from 60 to 80 cents per gallon. One gallon covered about 350 square feet, and the cost of cleaning the surfaces and applying one coat of paint cost, on an average, 60 cents per net ton of bridge material.

The results from the use of this paint have so far been excellent.

To summarize, the experience of the writer has led him to favor the following practice:

FOR NEW WORK.

1st. Thoroughly clean the surface with the sand blast and apply, at the shops, a priming coat of red lead and linseed oil and a second coat of asphaltic varnish, using special care where surfaces come in contact and are shop-riveted, or at parts that are inaccessible for field painting.

2d. Apply a third coat of asphaltic varnish paint, after erection.

REPAINTING BRIDGES.

If in bad condition, clean all surfaces with the sand blast and use a priming coat of red lead and oil, and a succeeding coat of asphaltic varnish, as specified for new work. In exposed places a third coat of asphaltic varnish should be used.

If the old paint is in fair condition, clean all surfaces from dirt, dust, scale, etc., and, after touching up all bare or defective spots with a preliminary coat of asphaltic varnish paint, apply one coat of the same paint.

The company should purchase and mix all ingredients of the paint to be used, taking great care to obtain only the pure, unadulterated articles. The majority of the patent paints that flood the market simply disguise, under euphonious titles, a conglomeration of worthless materials.

The importance of this subject, treating as it does of the armor that is the sole protection of our "permanent" steel bridges against the ravages of their mortal enemy, rust, is my apology for thus encroaching on your time and good nature.

VISITS TO SCIENTIFIC INSTITUTIONS IN EUROPE.

By Prof. Edward W. Morley, Ph.D., LL.D., Honorary Member of the Civil Engineers' Club of Cleveland.

[An address delivered before the Club, November 9, 1897.*]

Ladies and Gentlemen:

In an emergency caused by a disappointment to your Programme Committee, I agreed to say something to you about some of my visits to certain scientific institutions across the water. That one which, if I could tell you the whole story, would perhaps be the most interesting of all to this audience was the Imperial Institute at Berlin, the Physikalisch-Technische Reichsanstalt. It was planned mainly by the great Hermann von Helmholz, and was founded by a most noble donation from Siemens, whose name is well known to all electricians, as well as to other scientific men.

This institution is under the care of the Government. It is, as its name declares, an Imperial Institute. Its duties are twofold, as the adjectives in its name may indicate. One part of its functions is the study of many refined physical problems, some of them too extensive or too costly to be dealt with by private means, or even by the semi-public means of the great German universities. Another important labor of the institute is the verification of almost any precise mechanism or apparatus submitted to it for the purpose.

In order to illustrate to you the extent and variety of the work done in the Reichsanstalt, I took the published list of the work accomplished by it during the year in which my visit fell, and began to copy the titles, but it is too long to read to you.

Among the more strictly scientific labors it was pursuing, I will name a few. It was engaged in measuring the expansion of water more accurately than had been done before. It was measuring the weight of a cubic foot of steam, with reason to hope that the accuracy attained would surpass that attained even by that great master of accuracy, the famed Regnault. It was studying the change of elasticity of a glass bar or tube caused by changes in temperature; its elasticity at the freezing point and its elasticity at the boiling point of water differ 10 per centum in some of the glasses which were used, and but 1 per centum in others. It had prepared a most elaborate normal barometer, and

*Manuscript received December 13, 1897.—Secretary, Ass'n of Eng. Socs.

had compared with this the working barometer which is used for all ordinary purposes. It had made three series of measurements of the expansion of the three steel screws used in Fizeau's wonderful apparatus for measuring expansion. All this is work of a high order, and it is work very necessary to have done; and the Reichsanstalt has the facilities for doing it. They have a personnel of men competent to do it, and the superintendence of a man well fitted to lead in the doing it.

As a sample of the other kind of work done there, almost anything which you can mention as desirable to be verified can be verified there. They verify thermometers, or determine their errors, and furnish a table stating what corrections are needed for these errors. They verify the accuracy of screws; the leading screw of a lathe, for instance, or the screw of such a micrometer as has been made by two of our Past Presidents for the Yerkes Observatory. They measure the expansion of steel bars designed to become scales by receiving an accurate graduation into millimeters or other lengths, or to be used in making an astronomical pendulum. Riffler, for instance, has had the expansion of the steel rods of his pendulums determined in the Reichsanstalt. They investigate alloys desired for special purposes, or required to possess certain specified properties. One gentleman desired an alloy which should have no magnetic properties, and the Reichsanstalt studied the matter and furnished such an alloy. They investigate gyrometers, instruments for indicating the number of revolutions of a rotating axis by a continuous indication. They verify tuning-forks. If one is constructed to make 500 vibrations in a second, they can determine the actual number almost to the hundredth of a vibration in a second. They determine the durability of incandescent lights, and also their efficiency. All such questions and such forms of apparatus are submitted to the Reichsanstalt, and you would be surprised to learn for how small a fee the desired information is afforded. As you see, this is a pretty wide field of activity. In order to do such work, they employ a great number of trained scientific men. In Germany a trained scientific man will accept such a position, because it is considered honorable, and because it gives him a recognized and desirable social position. So the institution can command a high degree of talent and training for its work.

One day I met, in Berlin, two Americans whom I had the pleasure of knowing in this country, and we visited the Reichsanstalt together. That which most interested us was the magnificent institution as a whole. One most interesting apparatus was

one designed for the establishment of a standard of light. You all know that it has been proposed that the ultimate standard of light for all measurements should be the light given out by a certain area of platinum at its melting point. It will probably be some time before this proposed standard can be conveniently and practically applied. The Reichsanstalt has suggested, and is trying to prepare, an alternative source of light designed as a standard for comparison in all accurate measurements. This standard is one in which a given area of platinum is heated, not to its melting point, but to that temperature at which the quantity of light radiating from it and also passing through a given absorbent screen shall be precisely one-tenth of the whole energy radiated. Their screen consists of a tube, closed at the two ends by plates of quartz of a determinate thickness, and filled with distilled water; and the standard of light which they hope to make practical is to be derived from a given area of platinum heated to that temperature at which this screen of quartz and water shall transmit one-tenth and absorb nine-tenths of the whole energy radiated. In the apparatus which so greatly interested me four different observers were to look, at the same time, at this source of light, each having his different measurement to make.

The apparatus, too, with which they compare thermometers seemed to me a most interesting apparatus. They have means for maintaining constant the temperature of a liquid medium in which they place a number of thermometers to be compared, and the apparatus will maintain some temperatures constant within one-hundredth of a degree for hours. Think of the skill, think of the apparatus required to do that, and then think of a building larger than our City Hall, filled with such skill and such apparatus, and you have a suggestion as to what this Reichsanstalt really is.

In Paris there are two laboratories which greatly interested me. One of them is the physical laboratory of the Sorbonne. I had the pleasure of meeting there the professor of physics, of whom you have all heard within the last few years, Lippman, the inventor of the process by which photographs can be taken which, properly used, can be made to throw on the screen an image of the original in the colors of nature. Professor Lippman was very kind. He desired to have me shown around his laboratory for an hour, while he made ready the photographs and lantern, which he was to show me afterward. He therefore asked an assistant to accompany me, but, on reflecting that his assistant could not speak English, he dismissed him and prepared to go with me himself. Of course, I relieved him of that loss of time

by telling him that I could understand his assistant's French, though I could not guarantee that he would understand *my* French.

When I was brought back to Lippman's room he showed me twelve photographs projected on the screen. They are not such photographs as can be framed and hung on the wall; you cannot see them as you see water-color drawings, or as you see the Zurich photochromes.

In order to get the color of the original, your eye must take that position in which you have specular reflection from the source of light. Now, as an orator, I am bound to assume that you all know what specular reflection is. If you let the sun shine on a mirror, it reflects the rays of the sun in one definite direction. If you stand within this path, where you can see the image of the sun in the mirror, you see some part of the mirror illuminated by specular reflection,—namely, that part of it which the image of the sun seems to cover. And if this mirror were one of Lippman's color photographs, you would see the vivid colors of the original only where, in the mirror, you had seen the sun's image.

A water-color drawing is usually seen by what is called irregular reflection. The rough surface of the paper receives light from perhaps a single source, but reflects it in every direction. Whatever your position, you see the paper and the colors on it. But if a mirror is so perfectly polished that no irregular reflection is produced by imperfections remaining, and if it is lighted by a single small source of light, you can see it only in that position in which you can see the reflected image of the light, and you can see only as much of it as is covered by this image. To see the whole mirror, you must have a source of light so large that its reflected image seems to cover the whole mirror. This cannot be accomplished with any practicable source of *intense* light, and Lippman's photographs require an intense light.

So Lippman's color photographs cannot be seen with the unaided eye, for the simple reason that we cannot procure a light large enough to illuminate the whole picture by specular reflection. The eye is too small. But if we put the photograph in the lantern, where it is illuminated from a source of light so wide that every part of it can return light to the projection lens, we can put on the screen a sight of the whole photograph, illuminated by specular reflection, and the whole audience can see the colors of the original objects.

These colors are wonderfully perfect. Lippman showed me a pair of photographs of a bouquet of bright-colored flowers.

The first photograph was taken indoors, by diffused daylight. I thought it was a magnificent reproduction of natural colors. Then he showed me the second photograph of the same bouquet, in the same aspect, but in bright sunlight. I am sure, could you have seen it, you would have been as delighted as I was; perhaps you would have been as much instructed as I was. I suppose that most of us seeing a bouquet in a good light, though not direct sunshine, and afterward seeing it in full sunshine, think its colors are the same.

Such is the influence of prejudice. These color photographs show most brilliantly that objects in sunlight and in diffused daylight by no means have the same color. But most of us, except an artist in water-colors whom I see present, no doubt are so under the influence of prejudice that, having seen a purple flower, we suppose it is always purple, and always the *same* purple.

> "A primrose by the river's brim,
> A yellow primrose was to him,

and it was always the same yellow. I was surprised to see the wonderful difference in absolute color when the object was placed first in one light and then in another.

Flesh-tints, also, were reproduced with wonderful fidelity. It is not yet possible to take portraits; the exposure required is too long. But Lippman avoided this difficulty sufficiently to enable him to show the capacities of his process in reproducing tints which are so difficult as flesh-tints. He did this by photographing a young girl lying on the grass among flowers. She could not maintain absolute repose, but she was so supported, and the area covered by the image of her face was so small, that the motions inevitable in an exposure of five minutes did not interfere with the general pictorial effect, and the flesh-tints seemed to be perfect.

There are other laboratories in the Sorbonne. In one of them I had the pleasure of meeting a gentleman who has done some of the same sort of work as that which I have done with oxygen and hydrogen. But I must not weary you by describing them.

Another institution in Paris which I must pass without description is the Conservatoire des Arts et Métiers. But I desire to mention a trifling incident which illustrates the exquisite courtesy which it is fair to expect in France. I was looking at the balance used by Regnault, of great interest historically, of special interest to one who has used a balance as I have done. It was so protected by a silk cord that I could not approach it as nearly as I desired, and a keeper or janitor who was present was

unable to permit nearer approach without orders from the office, to which he directed me. As I was going upstairs toward the office I met a gentleman coming down. The workman's French was not that of Ollendorff, and I had but a vague idea where to find the office, and so asked this gentleman if he would direct me. He spoke such French as I could easily understand (although not like that of Ollendorff), and said to me, "I am from the office; perhaps I can spare you the going upstairs to it?" I explained, and although he was just leaving the building for other duty, or perhaps pleasure, and although a word to the janitor would have done all I had asked, he took half an hour to show me all I desired to see, and endeavored to keep me longer. As he did not know my name, and as my name could have made no impression on him if known, this may be taken as a sample of the courtesy which is given to strangers by gentlemen in France. It was consistent with my uniform experience in that country; my experiences in Germany were not so pleasant.

The other institution in France which interested me was the International Bureau of Weights and Measures. Some twenty years ago, most of the governments of the larger civilized states united in appointing an International Committee of Weights and Measures, in the hope of preparing accurate copies of the meter and the kilogram.

There is no measure of length, except the meter, which is not too ambiguous for general use. I once read a statement which had been copied from German into French, and then from French into English, which gave a certain length in inches and thousandths of an inch. I was interested to know the precise length intended. The question to be answered by conjecture was, What foot and inch were those used in the statement—the English (for the statement is now in English) or the Paris foot (for the statement was last in French), or one of the many various German standards of confused length (for the statement was first made in German, and almost every German petty state had its own contribution to the confusion of standards of length)? The only solution of the whole matter was, that the truth could not be learned from the announcement, unless I could find whether the Austrian author had used the Austrian standard, or that of Heidelberg, where he wrote; or that of Leipsic, where publication was made; what course the French translator took, and what the English. If Mr. Warner wrote the statement, and it was published in New York, conjecture would be safe; or if an Englishman wrote and London published. But when you consult the literature of precise meas-

urements which is worth translating, the meter is the only standard of length which is not ambiguous, and the same is true of the kilogram. How many different pound weights are there?

Now, as I said, the principal civilized governments united in forming this International Committee of Weights and Measures. This international committee, with the help of a French committee, have performed their task, and the mechanical and physical and practical work has been done a few miles from Paris, at Sèvres, in the Pavillon Breteuil, which was once a fine summer palace. This is now the home of the International Bureau of Weights and Measures. I went there one day, fresh from a long stay in England. In that country, if you desire access to almost any of the places which were likely to interest me, affidavits of respectability, in the shape of letters of introduction, are most essential, and I went to England in such health that letters of introduction were far from my thoughts. I went up to the high fence around the International Bureau without much expectation of getting access. In fact, one day I went there, and went away without even making application for admittance. But on another day, as I approached the gate, a gentleman who had been standing there was just going away as he saw me. He courteously lingered, and turned back to the gate. I told him that I was a stranger, and that I had followed their work with great interest, and wished to see what could properly be shown to a stranger. I could not suppose that he had ever heard my name; but I do not know how a man could have received an acquaintance with more cordial courtesy than he showed me. He welcomed me; he introduced himself to me, and introduced me to the head of the Bureau and to the third of the three scientific men of the establishment. Then the three took turns, each showing me that part of the equipment with which he was most conversant. I saw nothing abroad which interested me more than this institution, but I could not hope to transfer this interest to you without diagrams and photographs. There was the comparer with which they have verified the length of those wonderful platinum-iridium meters, of which our own Government has received two or three. I had seen the meters which our own Government received. I had been invited to Washington, to be present when the standard meter was to be unpacked from the box in which it had been sealed at this International Bureau at Sèvres. The superintendent of the Coast and Geodetic Survey, desiring to have some ceremony testifying to the importance of the event, had asked the heads of bureaus at Washington whose duties made them inter-

ested in standards of length or weight, and the presidents of societies of engineers, and some of us plain professors also interested in such standards, and I had the honor to be among the latter. The seals were broken in the Cabinet room by the President of the United States and his Secretary of State, and an instrument was drawn up and attested by the signatures of all the gentlemen present. That was my first acquaintance with the platinum-iridium standard meter of the United States, and it was most interesting to see the apparatus used in making it the most authoritative standard of length now existing within our country. I saw also at Washington the platinum-iridium kilogram which had also been sealed up at Sèvres and sent to this country and opened at the same time. On my visit to Sèvres I saw a most consummate flower of mechanical skill in the four balances with which the work on that kilogram and on the smaller weights, required in the investigations, had been accomplished. These were balances nearly like the one which I used for some time. They have brought a new precision into the art of weighing. I suppose scales which weigh a ton of coal within 10 pounds are as accurate as commercial scales of that capacity need to be. Now, scales weighing a ton of coal would have to indicate the difference produced by adding to their load a piece of writing paper a quarter of an inch square, in order to equal, in precision and delicacy, the four balances which I saw at Sèvres. One illustration of their accuracy has been mentioned several times. I have mentioned it in this place. I may remark that I once heard this illustration repeated, to my no small amusement. I sat at a banquet and heard a physician of this city tell of a wonderful balance in one of the departments at Washington, which had the degree of accuracy which I will mention shortly, and I sat pleased and silent, for that balance was in my laboratory, and there was none at Washington. The story which the physician told was this: These balances are so delicate that, if you first put two one-pound weights side by side on one pan and counterpoise them, then, if you put one of the two weights on top of the other, the counterpoise will be too heavy, for one of the weights is now farther from the center of the earth than before, and the action of gravity on it is lessened. Such an infinitesimal as this is quite within the delicacy of the instrument. I do not mean to say that one, or even ten, weighings would be sufficient to determine so small a difference. It is to be detected only by long and painful labor. But the error produced by weighing two pound weights, sometimes side by side and sometimes one upon the other, is a

quantity *capable* of being detected by this balance, and it is a quantity which is to be considered in the reduction of all weighings made with it.

There was a barometer there the like of which has not been produced elsewhere, and an air-thermometer like the barometer. Regnault said, some fifty years ago, that between the freezing and the boiling point of water it was hard to measure a temperature much closer than a tenth of a degree. And he was right. But the Bureau at Sèvres has labored at this matter until, within those limits, it is possible to measure to the hundredth of a degree more accurately than to the tenth of a degree fifty years ago. A great increase of our knowledge of the behavior of materials will thus result from the investigations at Sèvres.

One thing which I saw at Sèvres gave me a feeling of sadness. Years ago I had devised a method of determining the weight of a cubic decimeter of water with great precision. I was pleased to see that most of my method had been reinvented at Sèvres, and saddened that I had not had, and was not likely ever to have, time, means and assistance to do so interesting and desirable a piece of work myself.

I must pass on to speak of some things in England. There were many things which I should like to mention. It would be pleasant if there were time to speak of Lord Kelvin's laboratory and lecture room at Glasgow, or of the fine laboratories at Manchester, and of interesting memorials of Cavendish and Davy which I saw there, the property of Professor Dixon, with whom I spent a most pleasant half-day. I should like to speak of King's College and of many things in London, but time fails me. I should like to speak of the Royal Society and of the Royal Society Club. This is the most interesting and important learned society in a country where, as I said the other day to an Englishman, all the scientific men in the country can get together every Thursday afternoon, if they choose. The country is not so widely extended as ours. We have to be content to meet a few scientific men once a year.

The British Association for the Advancement of Science made a great impression on me. In England almost all the scientific men—the greatest as well as the lesser—get together at these annual meetings. There is a wonderful power in this. The British Association is the only great success of that kind on the face of the earth. Similar French and German societies are qualified successes. Our own is but a qualified success. But in England every scientific man thinks it a duty and a luxury to

go to these meetings, and there is a wonderful inspiration in the assembly.

One matter of which I wish to speak is the Royal Institution in London. If there is any place in London in which an American ought to feel at home, it is the Royal Institution. It was founded by an American, Benjamin Thompson, afterward Count Rumford, of the Holy Roman Empire. I do not know what was his precise aim. The Institution is now somewhat unique. It is in some sort a scientific and literary club. Any one seems to be elected to membership on application, I think as freely as he could be admitted to our Case Library on paying his fee. The building has a library and a pleasant reading-room well supplied. It has also a good many Americana, including letters from Franklin and Washington, as well as other matters especially interesting to Americans. It has also important laboratories, in which some of the most memorable work yet done in science has been accomplished. You will agree with me when I recall to your minds that here Sir Humphry Davy worked and here his greatest discovery succeeded him in the person of Michael Faraday. At the present time Dewar is professor of physics here, and Lord Rayleigh, the discoverer of argon, is professor of chemistry. Lord Rayleigh's work is done at his private laboratory, an hour from London, which, of course, I could not see.

The munificence of an eminent English scientific man has lately added a new laboratory to the resources of London science, and this new laboratory is closely adjoining the older laboratories of the Royal Institution and under the management of those professors of the Institution who were just named, so that practically it is a new laboratory of the Royal Institution. This laboratory I did not see.

In the older laboratories of the Institution Dewar has done a great and important work in the liquefaction of gases. It is not that on precisely the process of liquefying gases he has added very much that is new, for gases had been liquefied by others; but, using liquefied gases as instruments of research, he, with certain gentlemen whom he has associated with him, has done a very important and interesting work. He showed me, partly with his own hands and partly at the hands of an assistant when he himself was busy, some experiments which would charm you, I am sure. First, he showed me the liquefaction of oxygen by an apparatus which we could set on this table, and liquefied a couple of ounces of oxygen within twenty minutes. In this

apparatus liquefied carbonic acid from an iron cylinder is made to stream through a long copper spiral, closely wound in such a way that, issuing from the lower part of the spiral, the gas is cooled by its sudden expansion, flows back over the other part of the spiral and cools it as well as the gas which will issue from the jet in the next moment, and in a few minutes you have this cooled to the temperature at which carbonic acid boils at atmospheric pressure. That cooling is applied to the second spiral, in which oxygen, at a pressure of fifty atmospheres, passes downward and is then permitted to expand to the pressure of the atmosphere. Having been already cooled to the boiling point of carbonic acid, the oxygen is soon cooled down to its own boiling point at atmospheric pressure, and then falls in liquid drops into a glass tube, in which you collect a shower of liquefied oxygen. The liquid was somewhat turbid. The gas had been procured, compressed in an iron reservoir, from some factory where oxygen is prepared for use in calcium lights, and contained some impurities. The liquid was filtered through paper, just as water might have been filtered, and was then a transparent, colorless liquid—a magnificent sight. In that was dropped a half-teaspoonful of absolute alcohol. Absolute alcohol does not freeze easily, but, when dropped into liquefied oxygen, it solidified, and then cracked into smaller angular fragments, as melted glass dropped into cold water cracks and flies to pieces. We took the solid absolute alcohol out and could not burn it till after we had warmed it to its melting point; it would not take fire. We dipped cotton wool in the liquid oxygen and touched it with a flame; it burned almost as if it were gunpowder.

Then I saw another apparatus for liquefying gases, used in researches at low temperatures. It had cost several thousand pounds sterling. One part of this apparatus was a gas engine of 25 horse-power, by means of which air was compressed to 200 atmosphere—to a pressure of 3000 pounds to the square inch. This compressed air was led through a tube, in which it was partly dried, and then through a spiral, like that which I mentioned before. The air was permitted to escape from an aperture at the lower end of this spiral, and the cooled gas then streamed up along the spiral and cooled it. In fifteen or twenty minutes, by maintaining the pressure of the air at 3000 pounds to the square inch and constantly releasing the gas at the lower end of this spiral, the spiral and the gas were cooled to the temperature at which the air liquefied and dropped like water. This apparatus is, of course, not portable, and its mechanical efficiency is but

1 per centum. To go in one step from ordinary atmospheric temperatures to the temperature at which liquid air boils at atmospheric pressure is a very long step. Something of efficiency must be sacrificed.

Then I saw a third apparatus, in which a double cooling was employed—first, from ordinary temperatures down to 50° or 100° Centigrade below the melting point of ice, and then, through a second step, down to the temperature at which air boils at atmospheric pressure. In this apparatus the mechanical efficiency was as much as 60 per centum.

I saw some of the apparatus which Davy used. But little of it remains—simply some suggestions of the great battery with which he decomposed the alkalies and discovered the alkaline metals. Some pieces of Faraday's apparatus were also to be seen.

Dewar was interested in the so-called X rays, and showed me the result of some experiments which he had just made on the transparency of different elements to these remarkable radiations. He made this the subject of a paper read before some learned society in London.

One other place which I visited in London was the office of the Warden of the Standards. London is a place which has grown. There is but little there which was built to order for its present use, one is tempted to think. Things are not often torn down in London; they are strong and lasting enough to be used for another purpose. And this Bureau of Weights and Measures, the office of the Warden of the Standards, was most interesting for this reason: One of the rooms in which standards are kept which have come down from the time of Queen Elizabeth is a chapel which is 600 years old. The very word "old" has a different meaning in England from that which it seems to possess in this country. Here the word "old" carries with it the suggestion, "Throw it away; get something new." With them the feeling is, that what is old is sacred, endeared, consecrated. The phrase "old fellow," as a term of endearment, was not invented on this side of the water. There it is at home; it is appropriate. I soon began to feel that there is no hope of salvation for a man in England who goes to a church less than 200 years old. In that old and venerable chapel, worthy of veneration, the old pound weights, the old gallons of Queen Elizabeth's time, seemed consecrated; seemed to have a glamor of romance and poetry about them. I never knew, till after visiting such scenes and seeing in them these special objects, how the meaning of the English language may change with change of longitude.

DISCUSSION.

Question.—I would ask the Professor if the tumbler of liquid oxygen is under atmospheric pressure.

Dr. Morley.—Yes.

Question.—What is the process by which it is again evaporated? What is its behavior?

Dr. Morley.—The liquid oxygen is kept and manipulated in glass vessels holding, perhaps, a pint and having double walls. Between the two walls is a very high vacuum. When the liquid air or oxygen is in such a vessel, protected by the non-conducting vacuum, very little heat reaches it, and it evaporates quietly at the surface, just as water evaporates from a tumbler of ice-water. The liquid oxygen, so used, looks like water; unless you notice the temperature of the liquid, you might well mistake it for water. But if you pour some of it into a vessel which does not protect the oxygen from the access of heat, it boils rapidly and disappears. In a common test tube a tablespoonful of liquid oxygen might last three minutes; in one of the vacuum jacketed holders a pint might last half a day. This is merely my conjecture; I have not seen the experiment made.

By Professor Langley.—Was there any visible tint of the oxygen?

Dr. Morley.—No; it looks just like distilled water.

Professor Langley.—Have they succeeded in producing hydrogen in anything more than a liquid spray?

Dr. Morley.—Dewar discussed that point; he had not, at that time, collected drops of liquid hydrogen in a tube where they could be seen.

Mr. Barber.—What is the lowest temperature which they are willing to give?

Dr. Morley.—The temperature of 220° Centigrade below the melting point of ice can be maintained at will by the evaporation of liquid oxygen at about a thirtieth of the atmospheric pressure. The temperature of minus 240 can be attained for a moment by cooling hydrogen down to minus 220, after compressing to perhaps 100 atmospheres, and then suddenly releasing it from this pressure. By a similar use of the newly discovered gas helium the temperature of minus 260 can be attained for an instant. Minus 273 is the ultimate limit, according to our present insight into the matter.

Dr. Howe.—I would ask Dr. Morley if it is not possible to see the colors in Lippman's photographs without a lantern?

Dr. Morley.—Yes; you can see the colors of some small

part of the photographs in their proper brilliancy, and the colors of the rest obscurely and somewhat altered in tint. In order to see properly the colors of the whole photograph at once, you need a source of light so large that its image in the reflecting surface of the photograph is as large as the photograph.

Lippman has been successful in reducing very much the time of exposure required to produce his photographs, and had some reason to hope for such further reduction that it would be possible to take portrait photographs.

It was interesting to hear him tell of his long search for a photographic film which should be sufficiently transparent. The film he uses has to be much thicker than in ordinary photographs. In those we have areas which are transparent and areas which are opaque; the contrast is sufficient if the transparency is not very great, and the opacity answers, even if the film is very thin. You may roughly compare an ordinary photograph to a gauze curtain having sewn to it a pattern cut out of some black cloth. With a light back of the curtain you can see the pattern clearly, even if the gauze stops a good deal of the light. But a Lippman color photograph is a much more complicated structure. Let me try to explain it, so that you may see why so thick and transparent a film is required. Let us imagine the thickness of the photographic film to be magnified a million times, so as to avoid speaking of minute distances. Then, at a point which shows yellow in the photograph, there would be seen something which I may compare to 100 or 200 gauze screens, all parallel to each other, all equidistant, one behind the other, and with an interval of 11 inches between successive screens. Each screen is to reflect light to the eye in front of the system. The whole system must be transparent, so that the light reflected from the screens most remote from the eye may pass through the intervening screens and reach the eye of the observer.

The colors of these photographs are due to the interference of the light reflected from these different reflecting layers, likened to the successive gauze screens. In the case just mentioned, where the distance separating the successive screens is 11 inches, a wave-disturbance which had a wave-length of 22 inches would be reflected from the hundreds of different surfaces, so that all these reflections should add their separate effects and give the sensation of yellow; but a wave-disturbance of some other than 22 inches wave-length would be quite lost by the counteraction of the separate reflections. So no color except yellow would show at the place in question.

These screens are produced within the substance of the photographic film. Let us imagine this substance to be represented, in our crude comparison, by filling the space between the gauze curtains with solid glass, or celluloid, or some other transparent substance. Then the light reflected from those screens more remote from the eye must pass through hundreds of screens, and also through a certain thickness of glass. The whole structure of screens and intervening substance must be transparent in a high degree. So Lippman's film must be very transparent, and must develop reflecting surfaces (at intervals of the thirty-five-hundredth of a millimeter) which have sufficient reflecting power and not too much opacity; for the light reflected from some of them has to pass through a multitude of others. It was very interesting to hear Lippman tell of his long search for a proper material.

I intended to say a word about the maker of the exquisite balance which was for a time in my laboratory, and those which are at the International Bureau of Weights and Measures. I went to see Rueprecht in Vienna. When I handed him my card he knew me, for we have had a good deal of correspondence. It was very pleasant to see his expressions of delight at seeing me, and my delight was as great as his. He knew well how much I like his balances, and showed me everything which could interest me. But it is too late now to say more.

I think most of us are well satisfied with our own country. I know that I am. I like to live in America; but it is to be confessed that Europe has, in some directions, the great advantage of an earlier start. The material equipments bestowed on the advancement of science, the leisure and the assistance afforded to a professor in a university, excited my envy and despair. Here we have reached the point where it is not too hard to get money for a university for—*the instruction of undergraduates.*

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIX. DECEMBER, 1897. NO. 6.

THE STRENGTH OF SEWER PIPE AND THE ACTUAL EARTH PRESSURE IN TRENCHES.

BY FRANK A. BARBOUR, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, November 17, 1897.*]

VITRIFIED clay, owing to its many excellent qualities, has been, and will be, extensively used in sewer construction.

Resisting well the wear of the stream, and proof against chemical action, it is economical and sanitary; and the smooth salt-glaze of a clay pipe affords a low coefficient of friction.

As an offset to these excellent qualities, however, little is known of its strength, and the constructing engineer of to-day, attacking the more difficult problems with their quicksand, deep cuts, water and underdrains, is often worried as to the possibility of failure of his pipe. If he doubts the safety of standard pipe he uses double strength, or resorts to concrete. The former costs usually 75 per cent. more than standard pipe, and the latter a still greater amount. Assuming the cost of pipe to amount to 12 per cent. of the total cost of average sewers, it appears that about 10 per cent. is added to the total cost by the use of the thicker pipe or concrete, and it is therefore an important question to determine where and under what circumstances it is necessary to use other than standard pipe. Again, since failures have occurred in several places with the double-strength pipe, it is important to determine whether these were due to poor pipe or poor construction—whether, in short, it is possible to get sufficient pressure on a good pipe, well laid, to break it.

*Manuscript received October 25, 1897.—Secretary, Ass'n of Eng. Socs.

As an answer to some of these questions, the experiments which this paper describes were designed. An attempt has been made to conform the experiments as closely to actual practice as possible.

The manufacturers of the sewer pipes most commonly used in New England were consulted, and they most cheerfully co-operated, furnishing to us such pipe as was needed.

The experiments may be divided into two sections; first, those to ascertain the strength of the pipe; second, those to ascertain the pressure created in trenches of varying depth and material by the filling itself and external weights.

In the breaking tests the pipes were laid in a trench exactly as in practice, and the pressure applied by an hydraulic machine to a platform resting on the filling over the pipe.

In the tests of earth pressure the same machine was placed in the bottom of a deep trench, and the earth filled upon a platform resting on the plunger, which communicated the pressure to a gauge.

The tensile and compressive strengths of the pipe material have been studied by breaking briquettes and cubes, made by an inspector at the pipe works, and burned in the same manner as the pipe itself. While of little practical value in themselves, these results may furnish a basis of comparison to other experimenters, and possibly be of some value to the manufacturer.

A very simple hydraulic pressure machine was designed for the experiments. It merely consists of a shell or cylinder of cast-iron with a plunger which rolls in a rubber diaphragm. The shell is cast in two parts, the upper portion having the cylinder-head cast with it; the lower has an open end, and the two parts are bolted together through heavy flanges.

The inside of cylinder and face of plunger flange were roughly machined.

The plunger is a plate one inch thick, strengthened by three webs $\frac{3}{4}''$ x $3''$, crossing at angles of 60°, with a flange $15''$ deep around the outside, which forms the working surface. The diameter of this plunger is $23\frac{1}{4}''$, or four times the thickness of the rubber diaphragm less than the diameter of the cylinder.

The rubber diaphragm is of common construction in smaller sizes, but unusual in the present size. It was molded using the upper portion of the machine as the female mold and a special iron casting as the male. Two layers of cloth, with heavy coats of rubber on the outside and between them, were used in its construction, the thickness being 3-16 of an inch.

APPARATUS USED IN BREAKING PIPE.

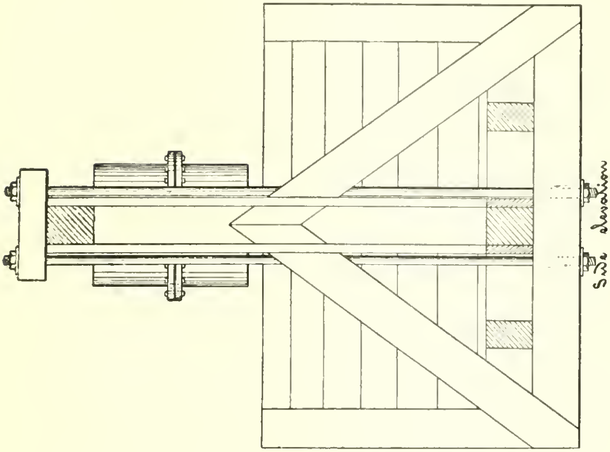


FIG. 1, *b*.

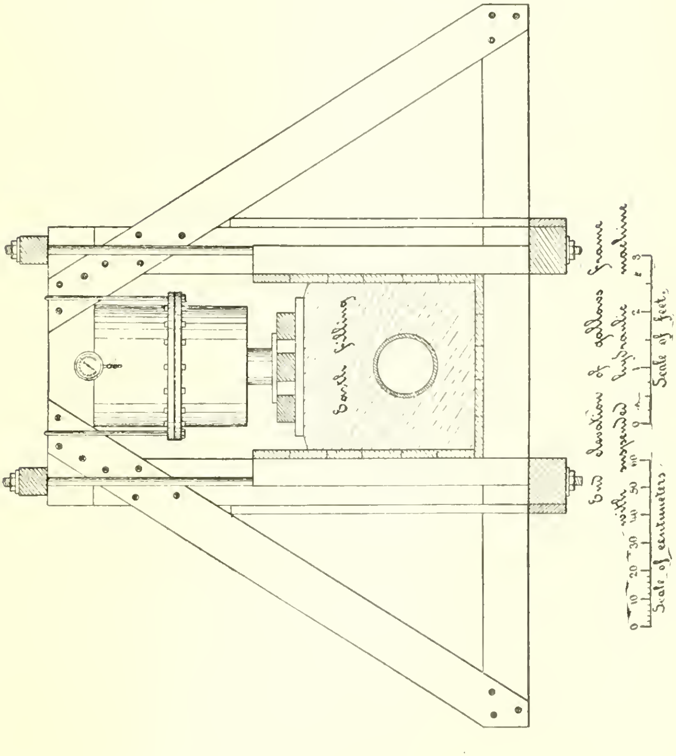


FIG. 1, *a*.

The shape of the diaphragm, as made, is like a round hat with a rim about two inches wide. In the machine the hat is upset and its rim caught between the flanges of the upper and lower sections of the cylinder. The plunger is then pushed up so that it rolls the crown of the hat inwardly, and the double thickness of rubber, being just the distance between the outside of the plunger and the inside of the cylinder, forms a rolling packing, perfectly water-tight, with little friction, and allowing a movement of fifteen inches safely.

The chief merits of the machine were cheapness, owing to the small amount of machine work, and the absence of leakage. The latter virtue was more evident in the experiments of trench pressures, where any leakage, such as would be probable with an ordinary piston, would have made the experiments almost impossible.

Water pressure was obtained from a windmill tank, and where this was insufficient, a small force pump was used.

To reverse the machine, the water was removed by a siphon, the longer leg of which was low enough to create sufficient head to rapidly raise the plunger.

The gallows frame, on which the machine was hung, is well shown in the plan and photographs. It consists essentially of two upright 8″ x 10″ hard pine sticks, mortised into two longitudinal sills of the same size and material, spaced 3.0 feet apart and capped by hard pine of same dimensions. Oblique braces extend from the uprights to the longitudinal sills, and also to a transverse sill. Four 2″ iron rods passing through the sills and maple blocks which crossed the cap, held the frame together. Two-inch planking was nailed to the inside of the uprights and to posts mortised into sills, forming a box 4.0 feet high, 3.0 feet wide and 8.0 feet long. The floor was made by planking, nailed to 6″ x 10″ floor beams spanning the sills. This box formed the trench in which the pipe to be broken was laid.

In all cases eight inches or more of earth was put in first, then the pipe was laid lengthwise of the trench, directly under the machine, and covered with earth, which was filled in in three-inch layers and thoroughly rammed. The ends of the pipe were sheeted up, a hole being left in the planks at each end to admit a candle for inspection. The sheeting was two inches longer than the pipe, and burlap was loosely stretched to keep the filling from falling down.

When the pipe was covered to the desired depth, a platform made of 2″ plank, held together by three 4″ x 6″ pieces of hard

wood, was placed on top, and to this the pressure of the machine was applied. The platform was always of the same length as the pipe, and thirty inches wide.

The pressure was carried from plunger to platform by a circular maple block eight inches in diameter, which gave a greater bearing surface than a metal rod. This block bore on a metal plate, which crossed the hard wood straps of the platform.

The depth of filling over pipe varied from six to eighteen inches. It was found that the amount of this filling made no difference, provided there was enough over the pipe to allow the

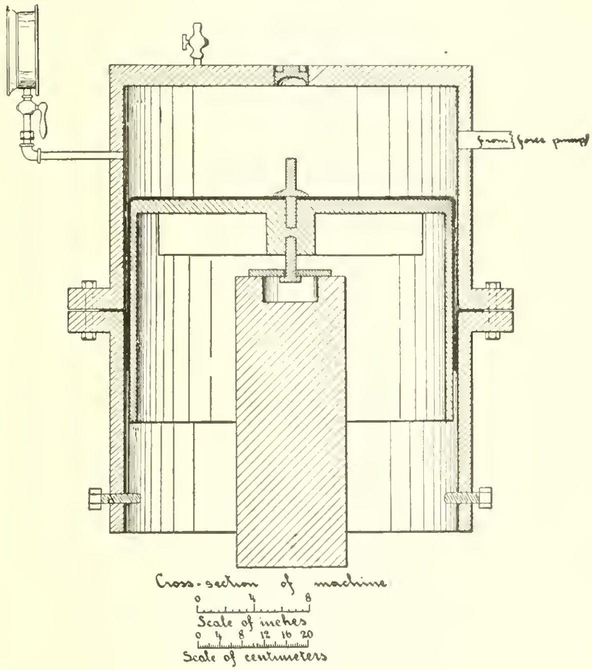


FIG. 1, *c*.

earth on the haunches to compress without bringing the pressure directly on crown of pipe. Six inches was sufficient to permit this.

It could not be assumed that the net effective area of such a plunger was equal to the area of the inside of cylinder, and a series of calibrations were accordingly made to determine this area. These were not all made at the same time, some being the result of a desire to know if the same coefficient of friction held good throughout the experiments, and were made at various times.

The method of calibration was to suspend from the long arm

of a 6″ x 6″ wooden lever a barrel of cement, and to balance by pressure applied to the short arm by the machine. The lever worked on iron rollers resting on iron plates, and all distances were measured accurately with a steel tape, the weight of cement and lever being carefully ascertained.

From readings of a vacuum gauge attached to the machine, taken with plunger ascending and descending, data was obtained from which it was easy to figure that the friction of machine equaled .245 pounds per square inch, and that the weight of the plunger was equal to .6 pounds per square inch. With the surface of plunger 1.2 feet below zero of gauge at moment of reading, a constant of .86 pounds had to be added to gauge reading to express the total pressure on short arm of lever.

The following table gives results of calibrations:

No.	Calculated Area.	Residual.	Square of Residual.
1	423.01	+4.18	17.4724
2	421.07	+2.94	8.6436
3	412.75	—6.08	36.9664
4	414.82	—4.01	16.0801
5	420.77	+1.94	3.7636
6	420.58	+1.75	3.0625
7	418.11	—0.72	.5184
	418.83		

Probable error of mean value = ± .968. According to the method of least squares, this result is .968 inches greater or less than the true value. From notes taken at the time of calibration, it is believed that observations 3 and 4, owing to variation in the height of plunger at the time of reading gauge, and the consequent change in the constant to be added to gauge reading, are too low, and the area—for the sake of even figures—will be called 420 square inches. This will be within a small fraction of one per cent. of the true value.

As it was found to be impracticable to note the height of the plunger in all the pipe breaks at the moment of reading gauge, and as the average breaking pressure was about 40 pounds, and the gauge could only be read to one-quarter of a pound, it is evident that the error in calibration of plunger is well within the limits of error of the other factors.

It is evidently needless to carry accuracy any further than the least unit to be determined by observation admits of, and the probable result of all errors is less than one per cent.

Table 2 shows the complete log of results. The first column gives the size and brand, whether A or B, *d* indicating

double strength; the second gives the number of specimen broken; the third the time of applying pressure; the fourth the length of pipe without bell; the fifth the thickness in inches, so far as measured, and the sixth the gauge pressure in pounds.

Table 3, in the first seven columns, shows the averages of the preceding log of results. The eighth column, which gives the total load on the platform, is obtained by multiplying the net area of plunger, in square inches, by the gauge pressure, with the constant .8 pounds added (as explained above).

Dividing this total load by the length of pipe (as given in column 5 + .25 foot for the bell) gives the load per linear foot of platform, as shown in column 9. Column 10 gives the load per linear foot of pipe (figured as equal to internal diameter in width); thus, the platform being thirty inches wide, the load per linear foot of a 15″ pipe is just one-half that of the platform. Column 11 gives the load per square foot of platform—obtained by dividing column 9 by 2.5 feet (the width of platform). Column 12 gives the percentage which the minimum breaking load is of the average breaking load.

Columns 10 and 11 express the results of most interest and value; column 10, showing strength per square foot, forms the means of comparing pipe strength with earth pressure, which will be considered further on in this paper.

Column 9 is of interest to pipe manufacturers and engineers as an expression of the actual ability of the several sizes to carry loads applied over the span of the arch; that is, of the strength of the different sizes per span, and not per square foot.

An examination of this column shows the breaking load per linear foot to average about 2800 pounds for the standard pipe and 4200 for the double strength. The uniformity of the figures of this column has led to an attempt to express in formula the relation of thickness of pipe to the cracking strength per linear foot, for it is to be remembered that all these figures refer to cracking and not destruction of the pipe.

It has been found that the strength per linear foot varies inversely as the diameter and directly as a function of the thickness, which is very near the power whose index is 1.65. This is expressed by the following formula:

$$p = c\frac{t^{1.65}}{d} \quad \text{or} \quad t = \sqrt[1.65]{\frac{pd}{c}}$$

when p = pressure per linear foot in pounds; t = thickness in inches; d = diameter in inches, and c a constant equal to 33,000.

TABLE 2. SHOWING LOG OF RESULTS OF PIPE BREAKAGES.

Size and Brand.	Number of Test.	Time of applying Pressure, Minutes.	Length, Feet and Inches.	Thickness. Inches.	Gauge Pressure, Pounds.	Size and Brand.	Number of Test.	Time of applying Pressure, Minutes.	Length, Feet and Inches.	Thickness, Inches.	Gauge Pressure, Pounds.	Size and Brand.	Number of Test.	Time of applying Pressure, Minutes.	Length, Feet and Inches.	Thickness, Inches.	Gauge Pressure, Pounds.
6''-A.	1	9	2'.00''	.70	49.25	8''-A.	31	5	3'.00''	.82	91.75	12''-A.	61	3	3'.00''	1.04	51.25
	2	9	"	.70	61.75		32	5	"	.82	77.50		62	3	"	1.04	51.00
	3	4	"	.73	77.00		33	6	"	.83	86.25		63	3	"	1.07	70.00
	4	7	"	.73	74.25	8''-B.	34		2'.00''	.82	41.00		64	5	"	1.05	57.00
	5	5	"	.72	67.75		35	8	"	.82	52.00		65	4	"	1.05	55.25
	6	4	"	.72	79.00		36	7	"	.82	69.00		66	5	"	1.06	74.00
	7	5	"	.73	83.00		37	8	"	.82	36.00	12''-A.(*d*)	67	4	3'.00''	1.26	64.50
	8	5	"	.74	61.75		38	7	"	.82	61.00		68	4	"	1.26	81.00
	9	4	"	.72	63.00		39	6	"	.82	62.00		69	3	"	1.26	69.00
6''-B.	10	7	2'.00''	.66	65.00		40	7	"		52.00		70	4	"	1.26	84.25
	11	5	"	.66	74.25		41	5	"		61.00		71	6	"	1.26	75.00
	12	5	"	.70	69.00		42	5	"		71.00		72	5	"	1.26	76.00
	13	5	"	.66	56.00		43	5	"		49.00	12''-B.	73	5	2'.00''	1.00	42.50
	14	8	"	.66	95.25		44		"		65.50		74	6	"	1.02	57.50
	15	7	"	.66	70.50	10''-B.	45	7	2'.00''	.80	53.75		75	5	"	1.00	44.00
	16	5	"	.66	58.25		46	6	"	.85	63.50		76	5	"	1.00	41.50
	17	5	"	.66	56.00		47	5	"		65.50		77	5	"	1.00	41.50
	18	5	"	.66	63.50		48	5	"		66.50		78	5	"	1.00	35.00
	19	5	"	.68	79.50		49	4	"		49.00	15''-A.	79	2	3'.00''	1.24	42.00
	20	5	"	.70	86.25		50	5	"	.83	65.00		80	3	"	1.24	62.50
	21	5	"	.66	70.25		51	3	"		32.00		81	4	"	1.24	52.25
	22	4	2'.00''	.68	64.00		52	3	"	.84	48.00		82	4	"	1.24	54.50
8'' A.	23	5	"	.78	25.25		53	5	"	.84	67.50		83	4	"	1.22	48.00
	24	7	"	.78	25.00		54	5	"		47.50		84	4	"	1.22	55.00
	25	6	"	.78	34.75		55	6	"		42.00	15''-A.(*d*)	85	6	3'.00''	1.46	85.50
	26	7	"	.78	35.50	12''-A.	56	6	2'.00''	1.00	24.00		86	5	"	1.46	75.00
	27	7	"	.78	35.25		57	5	"	1.04	24.75		87	5	"	1.44	65.50
	28	6	"	.78	39.75		58	5	"	1.00	23.75		88	5	"	1.44	71.00
	29	4	3'.00''	.82	72.25		59	4	"	1.00	22.25		89	4	"	1.44	63.50
	30	6	"	.82	98.00		60	5	"	1.04	28.75	15''-B.	90	4	2'.00''	1.08	28.25

TABLE 2. SHOWING LOG OF RESULTS OF PIPE BREAKAGES—*Continued.*

Size and Brand.	Number of Test.	Time of applying Pressure, Minutes.	Length, Feet and Inches.	Thickness, Inches.	Gauge Pressure, Pounds.	Size and Brand.	Number of Test.	Time of applying Pressure, Minutes.	Length, Feet and Inches.	Thickness, Inches.	Gauge Pressure, Pounds.	Size and Brand.	Number of Test.	Time of applying Pressure, Minutes.	Length, Feet and Inches.	Thickness, Inches.	Gauge Pressure Pounds.
15″-B.	91	4	2′.00″	1.12	34.25	18″-B.	121	5	2′.00″		23.00	20″-B.	151	4	2′.00″		19.25
	92	4	"	1.15	33.00		122	5	"		20.25		152	4	"	1.28	18.75
	93	4	"	1.15	29.00		123		"	1.22	21.75	20″-B.(*d*)	153	4	2′.00″	1.76	18.75
15″-B. (*d*)	94	6	2′.00″	1.36	59.00		124	5	"		18.00		154	5	"		28.50
	95	4	"	1.36	39.00	18″-B.(*d*)	125	6	2′.00″	1.53	38.50		155	5	"		26.75
	96	5	"	1.36	58.50		126		"		36.00		156	3	"		23.00
	97	5	"	1.36	42.00		127	6	"		36.00	24″-A.	157	3	2′.00″	1.47	14.50
	98	4	"	1.38	41.50		128	5	"	1.52	33.75		158	3	"	1.48	15.00
	99	4	"	1.36	39.00		129	5	"	1.52	37.25		159	4	"	1.48	12.25
18″-A.	100	5	2.′00″	1.46	25.25		130	2	"	1.52	39.50		160	3	"	1.48	12.75
	101	5	"	1.44	30.50	20″-A.	131	4	2′.6″	1.29	26.75		161	4	"	1.48	14.00
	102	5	"	1.40	18.75		132	6	"	1.29	27.75		162		"	1.48	20.50
	103	5	"	1.40	17.25		133	3	"	1.29	26.75	24″-A.	163	4	2′.6″	1.46	22.00
	104	5	"	1.42	21.25		134	3	"	1.30	23.75		164	4	"	1.46	22.50
	105	2	"	1.44	30.75	20″-A.(*d*)	135	5	2′.6″	1.70	30.75		165	4	"	1.46	23.75
	106	6	3.′00″	1.26	31.75		136	6	"	1.72	46.25		166	4	"	1.46	23.25
	107	5	"	1.26	31.00		137	5	"	1.72	46.00		167	5	"	1.46	24.75
	108	5	"	1.26	31.75		138	6	"	1.72	30.00	24″-A.(*d*)	168	6	2′.6″	2.02	36 00
18″-A.(*d*)	109	7	3′.00″	1.54	56.00		139	5	"	1.72	39.00		169	5	"	2.02	34.00
	110	8	"	1.54	55.00		140	5	"	1.72	46.00		170	4	"	2.02	34.00
	111	4	"	1.54	58.75	20″-B.	141	3	2′.00″	1.32	14.75	24″-B.	171	1	2′.00″	1.48	11.75
	112		"	1.54	40.25		142	3	"		16.00		172	1	"	1.48	13.50
	113	3	"	1.56	49.00		143	3	"		14.25		173	2	"		14.00
18″-B.	114	5	2′.00″	1.17	31.25		144		"		16.75		174	2	"		12.00
	115	4	"	1.16	30.75		145		"		20.75		175	1	"		13.00
	116	4	"		21.50		146	3	"		28.00		176	2	"		14.25
	117	4	"		26.50		147	4	"	1.34	21.24		177	3	"		19.00
	118	5	"		22.50		148	4	"	1.30	17.25		178	2	"		15.00
	119	4	"	1.16	20.00		149	4	"	1.34	18.00		179	4	"	1 47	17.00
	120	5	"	1.16	27.50		150	3	"		18.25		180	4	"	1.49	21.75

TABLE 3. SHOWING AVERAGES AND PRINCIPAL RESULTS OF BREAKAGES.

Size of Pipe.	Brand.	Number of Pieces Broken.	Time of applying Pressure.	Length without Bell.	Thickness, Inches.	Gauge Pressure, Pounds.	Total Load on Platform, Pounds.	Load per Linear Foot of Platform, Pounds.	Load per Linear Foot of Pipe, Pounds.	Load per Square Foot of Platform, Pounds.	Percentage of Minimum Break.
STANDARD.											
6″	A	9	5.8	2′.00″	.72	68.55	29127	12945	2589	5178	72
6″	B	13	5.5	2′.00″	.67	69.87	29681	13191	2638	5276	80
8″	A	6	6.6	2′.00″	.78	32.58	14020	6232	1662	2493	76
		5	5.5	3′.00″	.822	85.15	36099	11108	2962	4443	85
8″	B	11	6.5	2′.00″	.821	56.32	23990	10662	2843	4265	64
10″	B	11	5.1	2′.00″	.832	54.56	23251	10334	3445	4134	60
12″	A	5	5.0	2′.00″	1.02	24.70	10710	4760	1904	1904	90
		6	3.8	3′.00″	1.05	59.83	25465	7836	3134	3134	85
12″	B	6	5.2	2′.00″	1.00	43.66	18673	8299	3319	3319	80
15″	A	6	3.4	3′.00″	1.23	52.37	22331	6871	3435	2748	80
15″	B	4	3.9	2′.00″	1.13	31.12	13406	5958	2979	2383	90
18″	A	6	4.5	2′.00″	1.43	23.96	10399	4618	2771	1847	72
		3	5.5	3′.00″	1.26	31.50	13566	4174	2504	1670	98
18″	B	11	4.6	2′.00″	1.18	23.91	10378	4612	2768	1844	80
20″	A	4	4.1	2′.6″	1.29	26.25	11361	4131	2754	1652	77
20″	B	12	3.5	2′.00″	1.32	18.60	8148	3621	2414	1448	77
24″	A	6	3.4	2′.00″	1.48	14.83	6564	2917	2334	1167	82
		5	4.2	2′.6″	1.46	23.25	10101	3673	2938	1469	95
24″	B	10	2.1	2′.00″	1.48	15.12	6686	2972	2377	1188	78
DOUBLE STRENGTH.											
12″	A	6	4.4	3′.00″	1.26	74.96	31819	9790	3916	3916	86
15″	A	5	4.9	3′.00″	1.45	72.10	30618	9421	4710	3768	88
15″	B	6	4.7	2′.00″	1.36	46.50	19866	8829	4414	3531	84
18″	A	5	5.6	3′.00″	1.56	51.80	22092	6796	4077	2718	77
18″	B	6	4.8	2′.00″	1.52	36.83	15804	7024	4216	2809	92
20″	A	6	5.4	2′.6″	1 72	39.66	16993	6179	4119	2472	75
20″	B	4	4.2	2′.00″	1.76	24.25	10521	4676	3117	1870	77
24″	A	3	5.0	2′.6″	2.02	34.67	14897	5417	4334	2167	97

Table 4 shows the size, thickness and strength as found by the experiments, and strength as given by the formula of the standard and double-strength pipe, the figures being in general the average of results of brands A and B.

In the 10″ pipe only Tests 54 and 55 were taken. The laborer had, in the other 10″ breaks, been leaving in the earth under the pipes and forming a kind of cradle, instead of removing it entirely between breaks. This was the only case of the kind, and the change from the usual conditions seemed to justify the throwing out of all the 10″ tests except Nos. 54 and 55.

In the 12″ the A 2-foot lengths were also thrown out in striking the average for this size.

TABLE 4.

	Standard.			Double Strength.		
Size.	Thickness.	Strength by experiment.	Strength by formula.	Thickness.	Strength by experiment.	Strength by formula.
6″	.695	2613	3015			
8	.822	2902	2985			
10	.832	2834	2440			
12	1.024	3226	2862	1.26	3916	4028
15	1.18	3207	2890	1.405	4562	3855
18	1.29	2681	2790	1.54	4146	3738
20	1.305	2584	2560	1.74	4119	4113
24	1.47	2549	2598	2.02	4334	4382

Such discrepancies as are noticeable are believed to be caused by the natural variations in the burning of the clay, and it is thought that a more extended series of tests would show the result tending still nearer those of the formula.

Fig. 2 shows this formula expressed graphically for the different sizes of pipe, the ordinates being the thickness in inches, and the abscissæ the breaking load per linear foot, with the corresponding breaking loads per square foot for the different sizes added at the top of the sheet.

An examination of this diagram will show that sewer pipe, as made at present, is not of such relative thickness as to give the same strength in the different sizes.

Engineers may reasonably demand that standard pipe have a breaking load of 3000 pounds, and double strength 4500 pounds per linear foot, in all sizes.

It is fully realized that with the same strength per linear foot, a 6″ pipe is four times as strong per square foot as a 24″, and that therefore a uniformity, per linear foot, means little, so far as bear-

Breaking Loads Per Square Foot for Different Sizes.

6″ pipe	4000	5000	6000	7000	8000	9000	10000	11000	12000
8″ "	3000	3750	4500	5250	6000	6750	7500	8250	9000
10″ "	2400	3000	3600	4200	4800	5400	6000	6600	7200
12″ "	2000	2500	3000	3500	4000	4500	5000	5500	6000
15″ "	1600	2000	2400	2800	3200	3600	4000	4400	4800
18″ "	1333	1667	2000	2333	2667	3000	3333	3667	4000
20″ "	1200	1500	1800	2100	2400	2700	3000	3300	3600
24″ "	1000	1250	1500	1750	2000	2250	2500	2750	3000

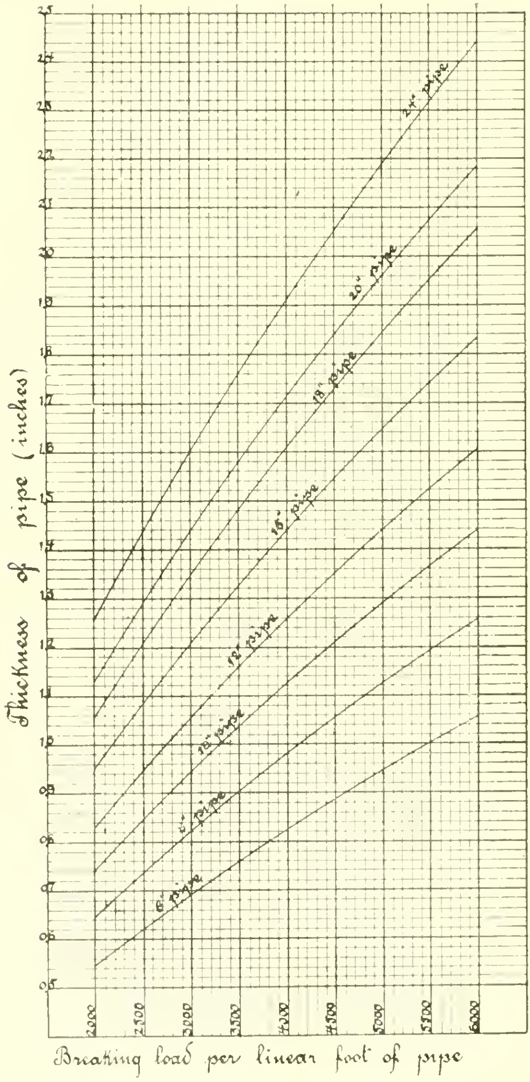


FIG. 2.

Relation between thickness and strength in vitrified clay pipe, calculated from the following formula:

$$p = c\frac{t^{1.65}}{d} \text{ or } t = \sqrt[1.65]{\frac{pd}{c}}$$

p = pressure per linear foot; t = thickness in inches; d = diameter in inches; c = consonant = 33000. Tensile strength of clay = 900 pounds per square inch. Compressive strength of clay = 6500 pounds per square inch.

ing strength goes. But in order to obtain the same strength per square foot, a 6″ would either have to be too thin, or a 24″ too heavy to handle, and for the sake of uniformity the unit per linear foot is recommended.

Whether future investigation will prove that the above formula expresses a relation between thickness and strength of pipe that will hold good generally, cannot be known except from experience. It represents fairly well the results of the pipe breakages described in this paper; and as the present thickness of the different sizes of pipe are not apportioned according to any rule, it is offered as an expression of the general case.

To obtain the recommended uniform strength per linear foot, of 3000 pounds for standard and 4500 pounds for double thick pipe, according to this formula, 10″, 18″, 20″ and 24″ standard will have to be increased to .94, 1.348, 1.437 and 1.605 inches respectively; and 12″, 15″, 18″ and 20″ double thick to 1.35, 1.543, 1.73 and 1.84 inches respectively, the other sizes being of the proper thickness at present.

Having a pipe of this known bearing strength, its factor of safety depends on the trench pressures, which leads us to that portion of the experiments.

The trench experiments, as before stated, were designed to ascertain the pressure created on a pipe, culvert, brick sewer or other structure built in a trench, by the superincumbent earth.

Common sense tells us that this pressure is not a multiple of the weight of earth per foot by the depth, but rather some fraction of this product depending on the nature of the material. To ascertain this net pressure in trenches the hydraulic machine, before described, was placed on two sills laid lengthwise in the bottom of a 13-foot trench, the cylinder being inverted and filled with water, which kept the plunger about the center of its movement. Everything being water-tight, there was no need of any pump, the water merely upheld the plunger and communicated the weight to the gauge.

On the plunger a block of pine, 18″ in diameter and 15″ high, was placed. On this, two 6″ x 4″ sticks rested and carried the platform, 5′-2″ long by 3′-3″ wide, on which the earth was filled. The machine and platform reduced the depth of trench available for experiment to 8.8 feet, which is the maximum depth of filling that was weighed.

The ends of the trench were in all cases sheeted, enough of the front sheeting being removed to permit reading of the gauge. The sides, likewise, to a point three inches higher than the platform,

were always sheeted, forming with the ends a permanent box in which the platform worked. A space of one inch was left in all cases between sheeting and edge of platform. To prevent the earth from falling through this crack to the machine below, burlap was loosely tacked to the platform and sheeting.

Above the level of the platform the sides were sheeted or not, as the conditions of the different experiments demanded. It is to be noted that while the sides were not sheeted in some cases, the ends were always sheeted. No rangers or braces were used on the inside of end sheeting, so that the recorded pressures must be higher, or on the safety side therefore, in every case, than in a continuous trench.

The first experiment was made with unsheeted sides, sloping from a bottom width of 4.0 feet to 6.0 feet at a height of 9.0 feet. The material used for filling was the loam as found at the Filter Beds, sandy, but damp enough to retain shape when pressed in the hand. It weighed 96 pounds per cubic foot.

The second experiment was made in same kind of a trench as the first, but the filling was in this case sand and gravel. This material would, according to the standard of the State Board of Health, have an effective size of .6 mm, not counting the stones which ranged from size of a pea to an egg, with perhaps two of the latter in each shovelful. The sand was sharp, and weighed 115 pounds per cubic foot. In the third experiment the sides were sheeted vertically and smooth, all rangers and ties being kept on the outside. The material used in filling in this and all the other tests, except No. 1, was the sand and gravel as just described.

The fourth experiment was made with sides sheeted on a slope of $\frac{1}{4}$–1, the width increasing from 3.8 feet at the bottom to 7.8 feet at the top.

In the fifth experiment the trench was dug out to a width of 8 feet at the level of the platform, the sides being vertical and unsheeted. The platform thus occupied 39 per cent. of the area of the bottom of trench.

The sixth and last experiment was made by once more sheeting the sides vertically, but instead of leaving the sheeting smooth, as in experiment 3, pieces of boards and plank were nailed to the sheeting in various ways to increase friction.

In these experiments one man backfilled while another rammed the material in the trench, the filling being made in six-inch layers, and readings of the gauge taken at the completion of each layer.

Table 5 gives, in the first column, the depth of filling measured

TABLE 5. SHOWING RESULTS OF TRENCH EXPERIMENTS.

First Experiment.			Second Experiment.			Third Experiment.		
Depth of Filling.	Net gauge Pressure	Ratio of gauge load to weight of earth, per cent.	Depth of Filling.	Net gauge Pressure.	Ratio of gauge to load weight of earth, per cent.	Depth of Filling.	Net gauge Pressure.	Ratio of gauge load to weight of earth, per cent.
1.2	4.15	82.2	.5	2.25	89.3	1.0	3.55	68.6
1.8	5.25	69.6	1.05	4.15	78.4	1.5	5.60	72.3
2.3	6.00	62.2	1.6	5.65	70.1	2.0	6.75	65.2
3.0	6.75	53.0	2.1	6.95	65.9	2.5	7.55	60.4
3.5	7.25	48.3	2.5	7.75	61.4	3.0	8.35	53.1
4.0	7.65	44.2	3.0	8.35	54.7	3.5	9.80	53.2
4.5	8.15	41.4	3.5	8.95	49.7	4.0	10.75	50.5
5.0	8.80	39.8	4.0	9.95	47.9	4.5	11.95	49.4
5.5	9.40	38.5	4.5	10.75	45.6	5.0	13.05	48.3
6.0	9.95	37.2	5.0	11.75	44.5	5.5	14.25	47.6
6.5	10.65	36.6	5.5	12.65	43.3	6.0	15.55	47.4
7.0	11.20	35.6	6.0	13.35	41.7	6.5	16.75	46.9
7.5	11.90	35.2	6.5	14.95	42.2	7.0	18.05	46.7
8.0	12.40	34.3	7.0	15.65	41.6	7.5	18.95	45.6
8.8	13.35	33.5	7.5	16.60	40.9	8.0	20.25	45.6
			8.0	17.55	40.5	8.8	21.75	44.4
			8.8	18.65	39.0			
Fourth Experiment.			Fifth Experiment.			Sixth Experiment.		
.5	.70		1.0	3.50	69.5	.5	1.15	45.6
1.0	3.65	70.5	1.5	5.05	66.8	1.0	3.65	72.5
1.5	5.65	72.1	2.0	6.05	60.2	1.5	5.55	73.4
2.0	7.00	67.6	2.5	7.25	57.4	2.0	6.45	64.2
2.5	7.85	62.8	3.0	8.05	52.7	2.5	7.45	59.0
3.0	8.95	56.9	3.5	8.85	49.2	3.0	8.25	54.0
3.5	9.85	53.4	4.0	9.95	47.9	3.5	9.15	50.8
4.0	11.15	52.4	4.5	10.60	44.9	4.0	9.75	46.9
4.5	12 75	52.8	5.0	11.65	44.1	4.5	10.55	44.7
5.0	14.35	53.0	5.5	12.65	43.3	5.0	11.25	42.6
5.5	16.15	53.9	6.0	13.95	43.6	5.5	12.25	41.9
6.0	17.75	54.1	6.5	14.55	41.7	6.0	13.20	41.2
6.5	19.25	53.7	7.0	16.65	44.2	6.5	14.05	40.3
7.0	20.75	53.9	7.5	17.75	43.8	7.0	14.65	38.9
7.5	22.35	53.9	8.0	18.65	43.0	7.5	15.45	38.1
8.0	23.75	53.5	8.8	19.25	40.3	8.0	16.25	37.4
8.8	26.05	53.2				8.8	17.45	36.5

from top of platform; in second column the net gauge pressure, and in the third column the percentage which total load by gauge is of weight of filling vertically over platform. This last column has been expressed giaphically in Fig. 3.

Experiments 1 and 2 were intended as a study of sloping unsheeted sides, the first filled with loam, the second with gravel.

Looking at the curves on Fig. 3, it is seen that in experiment 1 the percentage of weight of superimposed earth, transmitted to platform ranged from 76 per cent., with a depth of filling of 1.5 feet, to 33 per cent., with 9 feet; and in experiment 4 from 72 per cent. to 39 per cent. at these same depths, the curves crossing at about a depth of two feet. In the higher depths the greater

cohesion of the loam absorbs about 6 per cent. of the weight of earth.

Proceeding to experiment 3, these percentages ranged from 72.0, with 1.5 feet filling, to 44.0, with 9.0 feet filling. It thus appears that the sheeting of the sides causes 5 per cent. increase in the pressure transmitted to platform.

Considering next experiment 6,—trench sheeted as in experiment 3, but rough instead of smooth,—it is found that with the same depths these percentages range from 73.5 to 36.0.

Experiment 5 may be compared with experiment 2, the first made by digging out the trench to a width of 8 feet with vertical sides, the second with sides sloping from the width of platform at bottom to a width of 6 feet at top. Both were gravel filled and unsheeted on sides. Experiment 5 was made particularly to ascertain the net pressure on platform when it occupied only a portion of the bottom of the trench. The net pressure, as shown by curve, varies from 67.0 per cent., at 1.5 feet, to 40.0 per cent., at 9 feet, results very similar to those of experiment No. 2. This indicates that the pressure per square foot on *unsheeted* trenches is about the same whether vertical or sloped, and that there is no wedging effect from sloped sides, a pipe having to carry a load proportioned to its horizontal surface.

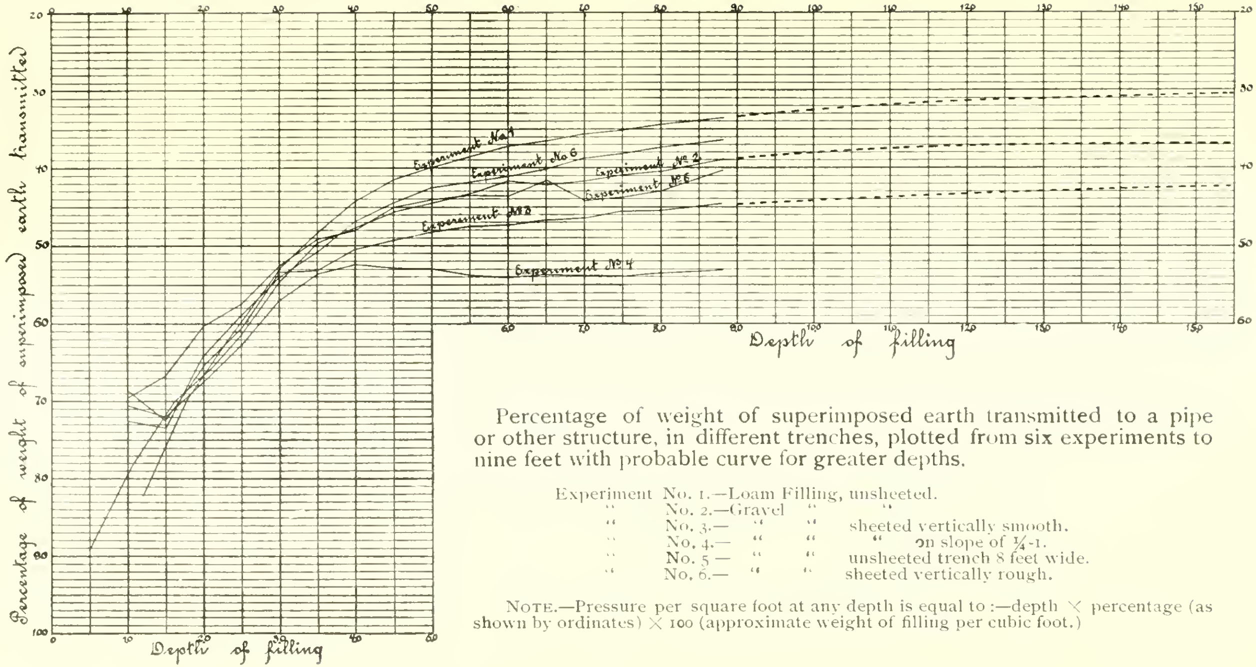
The fourth experiment, with sheeted sides sloped $\frac{1}{4}$–1, was made to study the wedging effect in such a trench. It is seen from the curve that the percentage of weight of superimposed earth transmitted to platform ranged from 72.0 per cent., at 1.5 feet, to 53.0 per cent., at 9.0 feet, being much higher than in the other experiments.

Looking over Fig. 3, the small difference in the results of the several experiments is very striking. Leaving out experiment No. 4 as an exceptional case, it is seen that the difference in net pressure is less than 10 per cent.

These results cover well all trench conditions *except the very important one of variation in the nature of the filling material.* The curves show that it is not the friction of the sides, but rather the cohesion of the particles of earth filling which determines the net pressure on the pipe. Experiment No. 5 seems to indicate that the width of trench, within limits, has little influence on this result.

Friction is a function of the pressure perpendicular to surface acted on, or in this case cohesion is a function of the lateral earth-pressure, and the relation of lateral pressure to weight of earth depends on the fluidity of material.

An examination of the diagram shows the cohesion rapidly increasing to a depth of about 5 feet, at which point the curves take



Percentage of weight of superimposed earth transmitted to a pipe or other structure, in different trenches, plotted from six experiments to nine feet with probable curve for greater depths.

Experiment No. 1.—Loam Filling, unsheeted.
" No. 2.—Gravel " "
" No. 3.— " " sheeted vertically smooth.
" No. 4.— " " " on slope of ¼-1.
" No. 5.— " " unsheeted trench 8 feet wide.
" No. 6.— " " sheeted vertically rough.

NOTE.—Pressure per square foot at any depth is equal to :—depth × percentage (as shown by ordinates) × 100 (approximate weight of filling per cubic foot.)

FIG. 3.

a more horizontal direction. As an explanation of this curve it may be offered, that up to a certain depth the rapidly increasing ratio of lateral pressure to weight of earth, and at the same time the rapidly increasing coefficient of friction, owing to lessened fluidity of material under pressure, together act to increase cohesion, or, in other words, lessen percentage transmitted to pipe. At the point where the earth filling becomes almost further incompressible, the coefficient of cohesion becomes constant and the curve approaches a horizontal straight line.

It will be noticed that in curves of experiments No. 1 and No. 2, the loam and gravel unsheeted trenches, that when the straight line is reached the percentage transmitted to pipe is about 31.0 and 36.0. These figures are equal to the difference between the coefficient of friction of loam and gravel, and unity. If we may extend this relation to other materials, we have a means of estimating the percentage of pressure transmitted by the more dangerous materials.

On this assumption it may be said that after the ratio of lateral pressure to weight has reached a constant which will be at depths about 10 feet, the percentage of weight of filling (or of external weights) transmitted to a buried structure will be the difference between unity and the tangent of angle of repose of the material in trench.

A wet clay with coefficient of friction equal to .35 will, on this basis, transmit 65 per cent. of its weight to a buried structure, and this may be considered the extreme case.

So far as the curves are based on experiment they are undeniably correct. It was rather a surprise to the writer to find that a 6″ layer of earth transmits its own percentage of pressure through 9 feet of filling which had been thoroughly rammed in 6″ layers, but such was the case, and we see no reason why this rule should not hold within any practical limits.

After completing the filling of the trench in experiment No. 2, thirty granite blocks, weighing 3750 pounds, were piled up on an area 2.0 x 3.35 feet. The gauge pressure was increased 2.05 pounds, or 23.5 per cent. of the actual weight of the stones was transmitted through 9 feet of gravel to the platform.

Repeating this on the trench with smooth sheeted vertical sides, 30.9 per cent. of weight of stones was indicated by increased gauge pressure. With rough sheeted sides 32.0 per cent. was transmitted to platform, and with trench 8 feet wide, as in experiment 5, only 19 per cent.

The net pressure is therefore invariably a smaller percentage

of weight of external object than that indicated by the diagram of net pressure of filling, and it will be well within the limits of safety to use the diagram in figuring net weight of external objects at different depths.

Accepting, then, these curves as of some value, and assuming the weight of earth as 100 pounds per cubic foot, it is only necessary to multiply the depth by ordinate of curve to find the net pressure per square foot at different depths.

Referring to Table 3, column 11, we find the breaking load per square foot of the several sizes of pipe as found by experiment, or, better, let us assume that all standard pipe are to be made of such a thickness as will carry an ultimate load of 3000 pounds, and double strength a load of 4500 pounds. Compare these figures with the results of the trench experiments and we have an expression of the ability of sewer pipe to stand probable pressure.

Table 6 is an attempt to express the factor of safety afforded by the different sizes of pipe, standard and double strength, up to a depth of 20 feet in a gravel trench. Column 1 shows the depth; column 2 the net pressure transmitted, as shown by experiment 2; column 3 the net pressure from road roller and filling at the different depths, and the other columns the factor of safety found by dividing the ultimate breaking load of the several sizes, as given at head of column by the figures of column 2.

From a careful study of the preceding table and a comparison of the results there indicated with such actual failures of sewer pipe as we have been able to investigate, 3 has been chosen as the necessary factor of safety.

Referring to Table 3, it is found that the average minimum breaking load is about 80 per cent. of the average breaking load. Therefore a factor of safety of 3, based on the average breaking load, is only equal to a factor of 2.5 based on the minimum breaking load.

The ultimate breaking loads of the pipes upon which the preceding table is based were obtained from pipe thoroughly well laid in an unyielding trench. The net pressures were, it is true, obtained from new trenches, and are probably much greater than in an old trench, but it is to be noticed that the figures are based on weight of filling alone, no live load being taken into account.

Take the extreme case of a road roller weighing fifteen tons, with perhaps six tons on each of the six-foot rear wheels, which are eighteen inches wide. With a surface depression of 6 inches, this means a load of about 2500 pounds per square foot over an area 1.5 x 3.3 feet, or much the same as the granite blocks covered.

TABLE 6. SHOWING RELATION OF STRENGTH OF PIPE TO PRESSURES IN TRENCH. EXPRESSED AS FACTOR OF SAFETY.

Depth of Trench feet.	Net pressure of earth. Lbs. per sq. ft.	Net pressure of earth and steam roller. Lbs. per sq. ft.	Factor of Safety.												
			6″	8″	10″	12″		15″		18″		20″		24″	
			Standard	Standard	Standard	Standard	Double Strength.	Standard	Double Strength.	Standard	Double Strength.	Standard	Double Strength.	Standard	Double Strength.
			6000	4500	3600	3000	4500	2400	3600	2000	3000	1800	2700	1500	2250
1	80	2080	75.0	56.2	45.0	37.5	56.2	30.0	45.0	25.0	37.5	22.5	33.8	18.7	28.1
2	130	1755	46.2	37.6	27.7	23.1	37.6	18.4	27.7	15.4	23.1	13.8	20.8	11.5	18.8
3	165	1540	36.4	27.3	21.8	18.2	27.3	14.5	21.8	12.1	18.2	10.9	16.4	9.1	13.6
4	190	1390	31.6	23.7	18.9	15.8	23.7	12.6	18.9	10.5	15.8	9.9	14.2	7.9	11.8
5	220	1320	27.2	20.4	16.4	13.6	20.4	10.9	16.4	9.1	13.6	8.2	12.3	6.8	10.2
6	250	1300	24.0	18.0	14.4	12.0	18.0	9.6	14.4	8.0	12.0	7.2	10.8	6.0	9.0
7	285	1310	21.1	15.6	12.6	10.5	15.6	8.4	12.6	7.0	10.5	6.3	9.5	5.2	7.8
8	320	1320	18.7	14.1	11.2	9.4	14.1	7.5	11.2	6.2	9.4	5.6	8.4	4.7	7.0
9	350	1325	17.2	12.9	10.3	8.6	12.9	6.9	10.6	5.7	8.6	5.3	7.7	4.3	6.4
10	380	1330	15.6	11.8	9.5	7.9	11.8	6.3	9.5	5.3	7.9	4.7	7.1	3.9	5.9
11	410	1340	14.6	11.0	8.8	7.3	11.0	5.8	8.8	4.9	7.3	4.4	6.6	3.6	5.5
12	440	1350	13.6	10.2	8.2	6.8	10.2	5.5	8.2	4.5	6.8	4.1	6.1	3.4	5.1
13	470	1375	12.8	9.6	7.7	6.4	9.6	5.1	7.7	4.3	6.4	3.8	5.7	3.2	4.8
14	505	1405	11.9	8.9	7.2	5.9	8.9	4.7	7.1	4.0	5.9	3.5	5.3	2.9	4.4
15	540	1435	11.1	8.3	6.7	5.6	8.3	4.4	6.7	3.7	5.6	3.3	5.0	2.8	4.1
16	570	1455	10.5	7.9	6.3	5.3	7.9	4.2	6.3	3.5	5.3	3.1	4.7	2.6	3.9
17	600	1480	10.0	7.5	6.0	5.0	7.5	4.0	6.0	3.3	5.0	3.0	4.5	2.5	3.7
18	630	1505	9.5	7.1	5.7	4.8	7.1	3.8	5.7	3.2	4.8	2.8	4.3	2.4	3.5
19	665	1540	9.0	6.8	5.4	4.5	6.8	3.6	5.4	3.0	4.5	2.7	4.1	2.2	3.3
20	700	1575	8.6	6.4	5.1	4.3	6.4	3.4	5.1	2.9	4.3	2.5	3.9	2.1	3.2

Column 3 gives the total effective load per square foot at the different depths of this live load and the earth filling.

Comparing these figures with the ultimate breaking load at the head of each column, it is seen that in such an extreme case the pipes have a very small factor of safety.

Any factor chosen must cover the variations in strength of pipe and the iniquities of pipe-laying, and it is believed that 3 is a factor of safety small enough to cover such contingencies in the safer trenches of gravel.

In such material as shown on Fig. 3 the percentage of pressure transmitted to pipe is about 35.0. If, as elsewhere discussed, as high as 60 per cent. may be transmitted in the more dangerous materials, in such cases a higher factor, based on this percentage, should be chosen.

Thus, while, according to the table, 20" standard is safe at a depth of 17 feet in gravel, in wet clay double strength should be used at this depth.

While appreciating the many elements of discord entering into trench work, capable of greatly altering such results as here presented, it is believed that some such basis of judgment may help to decide whether standard or double-strength pipe is necessary, and perhaps form a foundation for future observers on this subject.

Moreover, it is probable that if engineers should decide that the thicker pipe is necessary at certain depths, and increased quantities should be used, its price, which is at present out of all proportion to its cost, as compared with standard pipe, would fall to a level where it could reasonably be used.

SPECIAL RESULTS.

The following table shows the results of breaking special pipe which were marked as soft, medium and hard-burned by the manufacturer:

TABLE 7.

Degrees of Burning.	6 inches.	8 Inches.	12 inches.	15 inches.	18 inches	Average.
Soft	61	64	40	51	48	52.8
Medium	65	59	43	29	31	45.4
Hard	49	59		38	36	45.5

Only one piece of each degree of burning in each size was broken, so that the results are accordingly not especially trustworthy. So far as shown, however, little can be inferred as to the strength of pipe from the degree of burning. According to the

table, the soft pipe were 15 per cent. stronger than the medium and hard, which broke at about the same figures.

The soft pipe were a light chocolate in color, having a good solid body; not a pipe that would be condemned from its appearance, although lighter than is preferred by many engineers in New England.

The medium pipe were of the average appearance, such as were broken in the general tests, while the hard were of a bluish gray color, brittle and, in the opinion of the writer, overburned.

A careful study of the external color and the texture of the various pipe throughout the tests failed to furnish any satisfactory explanation of the variation in breaking load.

It has been noticed in the shale pipe, that low breaks are often found in laminated pipe—those which on breaking separate in concentric layers. This by no means explains all low breaks, but is an accompaniment of the majority of them. It would seem reasonable that this would be a cause of weakness. The laminations are probably caused by the lagging behind of the clay next to the inside and outside molds, and the forcing of the center clay ahead. Lubrication of the molds might prevent this action.

The noticeably low breaking strength of the 20″ B double-strength pipe is plausibly explained by the appearance, in the middle third of the thickness of the pipe, of a black streak resembling porous slag. While the average body of this pipe absorbed about 1.5 per cent. of its weight of water in 24 hours, this burned portion absorbed 4.5 per cent. in the same time.

It may be due to too quick water-smoking, or driving off of the moisture in the clay. Whatever the cause, it is an object of interest to inspectors, as it makes double strength no stronger than standard pipe.

The pipes usually break in four pieces in straight lines, through the center of the crown and invert and along the springing lines of the arch. When these lines, dividing the pipe into four equal sections, are not followed it is usually found that the crack is determined by a fire-crack or small stone. Thorough grinding and mixing of the clay is an important factor in the manufacture of good pipe.

In several cases pipes with fire-cracks several inches long have been placed in the trench so that the crack came half-way between the points of probable breakage, and the pipe stood the average pressure, breaking as usual into four parts.

Fire-cracks are undoubtedly an element of danger; and if the pipe is used it should be placed as described.

Attention has been already called to the fact that the breaking loads, as recorded in this paper, refer only to the cracking of the pipes, and not to their destruction.

In several cases attempts have been made to crush the pipes to destruction, but always without success. The gauge pressure was run up to over 100 pounds on 8″, 10″ and 24″ pipe, and, although the cracks at invert and crown opened ¼″, it was evident that the pipes would stand much more before destruction.

It may be said that with a good incompressible foundation a 24″ pipe, with sides and haunches thoroughly tamped, after being cracked, will stand a pressure of 10,000 pounds per square foot without collapsing.

This leads to a consideration of the value of concrete around pipes. It evidently merely serves as a good, unmovable foundation, and when this can be obtained with the material in the trench, concrete half-way up a pipe adds little strength. Where concrete in a bad trench is filled in solid between sheeting which is to be left in, the case is different. Several pieces of 8″ pipe were laid in concrete—4″ under pipe and 6″ on sides to half diameter of pipe. The pipes broke at 65 pounds gauge pressure, or 16 per cent. greater than the average ultimate breaking load of pipes in earth.

In an attempted study of the conditions under which breakages have occurred in practice, letters were written to all the places in New England where it was known that there had been failures. The sizes which have failed have usually been 18″ in diameter and upwards of standard pipe, but in three cases double-strength pipe has failed.

Except in one place, where pipe known to be of inferior quality was laid, the depth of cut has been from sixteen to twenty feet.

In almost all cases there is a reasonable cause of the failure in the conditions or methods of construction. Leverage of chimneys, unstable foundation, unequal settlement at manholes, washing of foundation into open joints of underdrains, are some of the reasons given for the failure of pipes.

All of these are causes beyond the ability of the pipe manufacturer to meet, causes which the engineer by proper care can overcome. In order to do this with any reasonable surety of result, the pipe should have a uniform strength to withstand pressure by proper proportioning of the thickness to the several diameters, and greater care on the part of the pipe manufacturers to study the determining conditions in burning.

To the uninitiated, clay burning, in its lower forms, appears a

most unscientific proceeding. Temperatures are judged by the eye, and necessary length of burning by specimens placed where they may not represent anything like the average burning of the kiln. The kilns are usually in the hands of an autocrat whose knowledge of the art is his capital, which he carefully keeps to himself.

It would seem as if the pyrometer, with electric transmission and the coal calorimeter might be used with advantage to put the knowledge of kiln burning on some more rational basis. It may be that the meteorological conditions are too potent a factor to permit any refinements; at any rate there is a great variation in the strength of pipe to-day, as witnessed by the low break of 8″ and 12″ A pipe, and considerable loss to the manufacturer from culling.

To sum up the principal results of this paper: Pipes of all sizes have been laid in trenches, covered with earth, and broken by pressure applied to a platform resting on filling, these conditions being as nearly like those of actual practice as it is possible to attain.

As the result of these breakages, a relation between thickness of pipe and strength has been expressed, and it is suggested that all pipe be made of uniform strength by properly proportioning the thickness to diameter—standard pipe to have a strength of 3000, and double strength 4500 pounds per linear foot when laid and covered with earth, so that the pipe is supported by well-tamped filling.

From experiments made in trenches with gravel and loam filling, the actual pressure at different depths has been ascertained and expressed as a percentage of the weight of earth superimposed. This percentage rapidly decreases with increasing depth, until at about 10 feet or less it reaches a constant value. This value, in the case of loam and gravel,—the two materials experimented upon,—was found to be equal to the difference between unity and the coefficient of friction of these materials.

If this relation may be extended to other materials, a means is afforded of estimating the actual earth pressures in trenches of all materials of which the coefficient of friction or angles of repose are known.

Comparing this actual earth pressure with the breaking strength of pipe per square foot, factors of safety for the different sizes of pipe at different depths are figured, and it is suggested from a study of known pipe failures in practice that 3 be provisionally chosen as the necessary factor of safety in gravel trenches, with an increased factor, based on angle of repose, for other

material. In this way a means of more readily deciding whether double-thick pipe or concrete is necessary will be afforded, and whether experience bears out its value or not it will at least form a foundation about which to group future judgments and results.

In connection with the breaking tests, an attempt has been made to determine the form of pipe joint which, while fulfilling practical requirements, would give the minimum leakage.

Special pipes 8″ in diameter were made, with joints varying from $\frac{1}{2}$″ to 3″ deep and from $\frac{1}{4}$″ to 1″ thick.

Over two hundred sets were made up and tested in the same manner as described by Mr. Freeman C. Coffin, in his paper on "Tests of Cement Joints for Sewer Pipe."

The assistant who made these tests was at first instructed to pack the cement into the joints with a wooden caulking tool, the mortar being of the consistency of dry mud. It was soon found that in this way almost any joint could be made so that, under a five-foot head, it would not leak enough to measure in three hours, and this has been considered as water-tight. No comparison of the efficiency of the different joints could be thus obtained, and accordingly the mortar was made more moist and the joint formed, as in practice, by a trowel and gloves.

The results have been decidedly unsatisfactory from the standpoint of a written report, and no tabulations of the figures will be given. It is believed, however, that in this irregularity, perhaps, information of value may be found.

All the work has been done by an assistant who knew nothing of the probable results, and who was instructed to treat each joint alike as to tamping and filling.

Tests of the time of setting and tensile strength of the cement were carried on at the same time, and proved the cement to be high grade.

The several joints experimented upon were as follows, the first figure indicating depth, the second width: $\frac{1}{2}$″ x $\frac{1}{2}$″, $\frac{3}{4}$″ x $\frac{1}{2}$″, $1\frac{1}{2}$″ x $\frac{3}{8}$″, 2″ x $\frac{1}{2}$″, $2\frac{1}{2}$″ x $\frac{1}{2}$″, 3″ x $\frac{1}{2}$″. For comparison the joints were made of neat cement, and not overfilled.

No very high leakage was obtained from any form of joint, the average being about 2500 gallons per mile; the lowest 850 gallons, with the $\frac{3}{4}$″ x $\frac{1}{2}$″; the highest 14,500 gallons, with the $1\frac{1}{2}$″ x $\frac{3}{8}$″ joint.

In the six-hour tests the Rosendale neat leaked 70 per cent. more than the Portland, the average of all joints being 3245 for Rosendale and 1900 gallons per mile for Portland.

In the eighteen hours tests, however, the difference is the other

way, the Portland leaking 10 per cent. more than the Rosendale, the figures being 1650 and 1485 gallons per mile, respectively. This is probably due to the slower set of the Rosendale, which only leaked 45 per cent. as much after an eighteen-hour set as after a six-hour set, while the Portland eighteen-hour leakage is 85 per cent. of the six-hour leakage.

The most noticeable result is the small leakage in the shallow joints, $\frac{1}{2}''$ and $\frac{3}{4}''$ deep. An examination of the cement removed in taking the joints apart, however, plausibly explains this result. In the shallow joint the cement is perfectly hard and compact for the entire depth, bonding well with the irregularities of the pipe, while in the joint $3'' \times \frac{1}{2}''$ only the upper portion is usually solid, the cement beneath being porous and full of air-spaces. This was obtained in joints which had been packed with trowel until the water flushed well to the surface. The clinging of the cement to the sides makes it difficult to thoroughly fill a depth greater than $1\frac{1}{2}''$ unless the width is proportionally increased, or efforts out of all comparison with actual practice are made.

The above results indicate that experimentally a joint $\frac{3}{4}''$ deep is as water-tight as one $3''$ deep made with the same effort. Of course, in practice the difficulty of keeping green cement from falling out of a shallow joint makes the minimum depth of joint greater than this.

It is not believed that the best depth is capable of experimental proof. The results which have been obtained showed comparatively little difference in the leakage of joints varying from $\frac{1}{2}''$ to $3''$ deep, except in the very narrow $\frac{3}{8}''$ joint, where it was six times as great as the average of the joints $\frac{1}{2}''$ wide. Leakage depends upon the depth of the surface hardening of the cement, and it is reasonable that unless the deeper joints are thoroughly compacted they should leak as much as the shallow joints. With the very narrow joint, however, not even the upper $\frac{1}{2}''$ was thoroughly filled. By "filled" is here meant absence of air-holes, however minute, because water, under a five-foot head, easily forces its way through such openings.

The effect of overfilling was tried with the $\frac{1}{2}'' \times \frac{1}{2}''$ joint and the advantages shown, the leakage being only 220 gallons per mile, or about 10 per cent. of the leakage through this joint without overfilling.

In the tests of mortar joints with 1 cement to 1 sand and 1 cement to 2 sand, the leakage differed but little from the neat joints, except that in this case the deep $3'' \times \frac{1}{2}''$ joint leaked much less than the shallow joints. It is reasonable that, so long as the

percentage of cement is sufficient to fill the voids of the sand, the leakage through the mortar made of clean, sharp sand and cement should differ little from that through neat cement.

In conclusion, it is believed that the following results have been indicated by the tests:

First. That experimentally a tight joint, under a five-foot head, can be made by using dry mortar and sufficient tamping.

Second. That from joints made more nearly as in practice little information can be obtained.

Third. That all joints should be overfilled.

Fourth. That joints less than $\frac{1}{2}''$ wide cannot be made tight without undue labor.

Fifth. That the difference between Rosendale and Portland cement joints is slight after an eighteen-hour set.

Sixth. That an overfilled shallow joint is as tight as a deeper joint, unless great care, such as is seldom taken in practice, is used to fill the deeper joint.

The deeper joint, however, better resists the dangers of pipe movement before set of cement and the injury from backfilling, and this consideration makes a joint deeper than one inch at least necessary. How deep it should be is a mere matter of judgment. The personal equation of the pipe layer and the inevitable disturbing elements of trench work render it of little use to figure that the leakage is affected by changes of fractions of an inch.

For the sake of the manufacturers, and indirectly of the consumers of sewer pipe, it would be well if some standard dimensions of pipe joints could be decided upon.

It is believed that a joint $2'' \times \frac{1}{2}''$ for pipes up to $12''$ in diameter, and $3'' \times \frac{5}{8}''$ for larger sizes, will, when overfilled, give as good results as can be obtained.

DISCUSSION.

Mr. F. Herbert Snow.—The city of Brockton was one of the first places to use the deep socket pipe designed by the late M. M. Tidd and put on the market by the Portland Stone Ware Company. We were satisfied that it was an improvement, and planned on purchasing more at the first opportunity.

It so happened, however, that the lowest bidders for furnishing the first large lot of pipe were the Akron manufacturers, who did not make deep socket at that time. I insisted that this kind of pipe should be furnished, and the local representative of the Akron people—being determined to secure the contract—induced one of the Commissioners and myself to go to Akron, make our

wants known, and prevail upon the manufacturers to accede to our request.

It was stated at the conference that the Eastern engineers were not only very particular, but also not agreed, regarding the proper depth of bell and width of socket, and that it was impracticable for the manufacturers to attempt to cater to the whims of every engineer. They finally agreed, however, to make what we wanted, and at least two of the factories went to the expense of getting out a new set of dies.

Later, the experiments of Mr. Freeman C. Coffin proved to us that we had done right in insisting on deep socket.

The experiments which we have conducted in Brockton seem to prove the standard socket to be preferable. I am of the opinion, however, that a satisfactory demonstration of this question by experiments in the laboratory alone is impracticable, because of the difference between the conditions under which the experiments must be conducted in the laboratory and those encountered by actual experience in the trenches.

We are not prepared to-day to alone take a definite stand regarding the proper dimensions of bell and width of socket.

There is as great a difference of opinion among Eastern engineers on the subject now as there was three years ago, and it would seem desirable that the matter be taken up and an attempt be made to reach an agreement between ourselves and the manufacturers.

Regarding the object of the experiments: On several occasions, early in the construction of the sewerage system, we had some doubt whether to use the old standard or the new double-strength pipe. A thorough discussion of the question did not remove the doubts. I explained the uncertainties of the matter to the Sewerage Commissioners, who looked into the question, and—wishing to conduct this public work as they did their private business, by eliminating all uncertainties so far as practicable, and believing that the cost of making certain experiments would be money well invested, since the results obtained might be of practical value to the city in the purchase as well as the use of the pipe—I was finally authorized and directed to proceed, and the paper which Mr. Barbour has read to you to-night has been made possible by these two years of experiments.

The manufacturers of the pipe mostly used in New England cheerfully coöperated from the first, putting themselves to expense and trouble, and we have carried the tests along with the hope that the results obtained might be an aid to some more

definite and satisfactory conclusion among engineers regarding the strength and dimensions of pipe.

I trust that this Society will manifest an active interest in the subject, and that finally the Sewerage Commissioners and the manufacturers may see the practical results of the money invested in the experiments.

Mr. T. Howard Barnes.—I am very glad that Mr. Snow has put this matter on the basis that he has,—viz, facts presented for discussion. Although I had the benefit of an advance copy, I have not had time to do very much in the way of food for thought in this discussion.

I think there are many points of interest covered by his experiments, and there are some questions that arise in my mind along the line of theories. First and foremost, as a demonstration, may be mentioned the extreme satisfaction that may be felt in thinking that, although the pipe may crack, if it is well packed around it will not break down; that is, it will possibly affect the leakage, but we do not have the mortification of digging that pipe out, and that is oftentimes the principle which may be adopted in cases where the presence of an occasional cracked pipe does not seriously affect our work. Those of us who have systems in the Metropolitan Sewerage District cannot do that, however, for the item of possible leakage both in and out is inadmissible.

There is one of the theories that come up as to the question of back-filling: what the effect would be of a pressure on the pipe in a very moist earth, consisting mostly of clay, which condition often occurs after a fall of rain or by puddling. It seems doubtful in my mind if the rule will hold which has been suggested.

Certainly, such a condition is liable to make a very much greater pressure on the pipe; but another question is, whether or no the pressure exerted will not be further lessened *in its effects* by the greater lateral pressure communicated. The fact that the ends of the trench are sheeted up in the experiments would seem to modify the deductions. In practice there would be no sheeting there, and the earth filling would transmit an applied stress back and forth over a more extended area.

It is human nature to be satisfied with conclusions which correspond with your own, and in that respect I am rather pleased with Mr. Barbour's conclusions in regard to joints and form of socket.

I had felt for some time that the shape in respect to the depth of socket was not enough; that, indeed, the depth was not the

principal item, but that we needed more width, and, more than all, we needed that whatever depth we had should be filled. That is the secret of tight sewers. It is the "*getting done*" of what we specify.

I took out a section of 8-inch pipe which shows a depth of socket of only $1\frac{3}{4}$ inches. The width is nearly $\frac{1}{2}$ inch at the mouth, and there is a slight flare, something like 15°. This specimen shows that the cement reached the bottom of the socket only in places. This was supposed to have been laid under very careful inspection.

I feel that the Society's thanks are due to the city of Brockton, Mr. Snow and Mr. Barbour for their very important results, for these facts presented to us, and that we may follow them up, as Mr. Snow has suggested, and make the most of them.

Mr. Henry Manley.—I do not desire to discuss the absolute merits of these experiments, as the subject is not in my special line of engineering; but I have had occasion to do some work that has a bearing upon it—a very heavy bearing, so to speak. We build in Boston a good many "assessment" streets, so-called, generally in the open country and for the benefit of the owners of the adjacent lands, who pay the entire expense. In these streets, under the law, the sewers, gas pipes and water pipes, with house connections for each house and vacant lot, must be in place before the street is surfaced. Consequently, I have had considerable experience in running steam rollers over recently filled trenches containing sewer pipes. This has been going on for seven years, and I do not at this moment recall an instance where the steam roller has injured a house sewer pipe.

In many of these streets there is an entirely separate and additional system of surface drains, which are laid at a much shallower depth, and in a few instances the steam roller has smashed those pipes, but in every such case it has been where there was a great depth of soft mud underneath the filling, and where the pipes were laid at a very shallow depth. Frequently they come within 18 inches of the subgrade, which is rolled with the steam roller, and the back-filling is often badly rammed and oftener not rammed at all. One of the chief uses of the road roller is to search out these badly filled trenches, and to allow the upper layers of the back-filling to be sufficiently consolidated to carry the roadway surfacing.

As I say, in seven years, covering a large amount of this kind of work, I do not recollect more than six or eight crosslines of drain pipe that have been broken.

In deeper sewers—brick sewers on piling, for instance, on soft ground—the sewer engineers (which, I would have noted, are an entirely separate body, that being a branch of the Street Department proper,) were apprehensive, in some cases, that the sewers would be injured by the roller.

It has long since been noted that the effect of the steam roller in consolidating material extends but a very short distance. When an excavation beyond a foot or two below the surface is made, no effect of the steam roller can be found, and on that account I was of the opinion that the roller would not be likely to damage the sewers. In one particular case, where there was a large-sized brick sewer, there was a considerable argument between the two kinds of engineers, and it was finally agreed that the sewer engineers should enter and place across the sewer a large number of struts—something like laths—that would be flexible, and that during the progress of the rolling they should be watched, and if any signs of movement occurred the work should be stopped. The street was rolled and the sewer was not injured. Since that time no precautions have been taken, except in cases where there is a very thin cover over the sewers, and no sewers have been injured, so far as is known.

Mr. J. A. Baldwin, of the Buckeye and Summit Sewer Pipe Companies, Akron, Ohio.—I am not accustomed to speaking in meetings. We are here by your kindness to see what we can learn, and learn what we can, as to your demands. We realize that, directly and indirectly, you are our largest customers, and as business men it is our interest to please you, to cater to your wishes as far as practicable, and keep in line with you. Perfect pipe are as scarce as perfect men. We know of three qualities in pipe that you all demand, and in these we strive to excel: First, to give you pipe of strength to carry any weight liable to be thrown upon it; second, an internal surface that will give the least possible friction, free from roughness or excrescences that will catch fibrous matter or obstruct the flow of sewer matter; and, third, a body absolutely impervious to the action of any matter that finds its way into sewers. In these respects we do our best to merit your favor. As to the depth of socket and space for cement, we were making such as we thought would give the best satisfaction to the largest number, but have made changes to cater to the demands of different engineers, and, by the paper read before us, we judge all are not now of one mind. As to what is falsely called double-strength pipe, we think the name misleading, as you only claim for it one-half added strength, and, from

the information we have, we think none will advise the thicker pipe for sizes smaller than 18-inch.

If not intruding, I would like to ask if, in your judgment, the few failures reported when pipe failed perfectly to carry the weight upon it, the failures would have occurred had greater care been used in laying; in short, whether the failures should not be charged to the careless neglect or iniquities of contractor or workman rather than to us manufacturers? As to demanding that the thickness of pipe be proportionate to the diameter, we feel it would without benefit add to the weight of small pipe and cause useless waste in making, in freight and handling. A variation of about one-sixteenth of an inch should be calculated in the thickness of the shell, because of the wearing of dies, and this in small pipe is very perceptible and material. The criticism of our pipe-burners seems hardly just. To burn successfully, one needs long practice and careful observation, watching not only the fires, but its effect upon the pipe while under fire; it is hard, faithful work twelve hours of the twenty-four.

I thank you for the privilege of the evening.

Mr. E. B. Winslow, of the Portland Stone Ware Company, Portland, Me.—It certainly has been a pleasure for a manufacturer of sewer pipe to meet here to-night with the Boston Society of Civil Engineers, and Mr. Barbour's paper certainly was very interesting.

There are a great many things about it that I might perhaps take up and discuss, but I will take but a few minutes. There are a few things I would like to touch upon, although I would prefer to sit still and hear Mr. Snow and Mr. Barnes and the other gentlemen talk upon this question of sewer pipe and the requirements of the engineers, rather than to attempt to impart any information to you myself.

I have never yet had an opportunity to have the engineers, either in a body or individually, visit our works that I have not derived some benefit from it. They always make some suggestions, and while in their specifications there may be some things that are difficult to meet, and there might possibly be some which we would not be successful in meeting, yet I have always made it a rule to satisfy the demands of the engineers. It has been in the past looked upon, when a contract was let and the specifications were submitted to the manufacturer, that it would be impossible for him to meet the requirements of that specification. I never have known it to fail, after the contract was awarded and the engineer had an opportunity to come to the factory, and if

he had not before had an opportunity to see sewer pipe made he would see at that time wherein it was difficult to meet some of the requirements of his specifications, and would modify them so that it would not be a hardship to the manufacturer.

We looked upon the inspector, in the past, when we started in with the rated inspection of pipe, as if that was a hard thing. I have outlived that. It has educated not only the proprietor of the works, but it has educated every man within the works, to the importance of making goods just as perfect as they can be made. There is not a man, I venture to say, working in the large sewer pipe manufactories of the country, where this inspection is carried on, who does not understand what it means when he is performing his part of the labor; that that pipe has got to go through a rigid inspection, and the man for whom he is working will be the loser if that pipe does not pass the inspection, and in that respect it has done a great deal toward affecting the quality of the sewer pipe put upon the market to-day.

In regard to the testing of pipe, Mr. Barbour's paper to-night is certainly very interesting, and, from a scientific point of view, is the first time I have had the matter called to my attention; but it is not the first time the manufacturer has had it tested underground, and sometimes it has not been just as he would like to have it. I have found, however, in a great many of those cases—I will not say always—what was lacking was an engineer. To illustrate: My attention was called to some pipe that had failed. I visited that place to see what was the trouble. I found the trench had been dug and had continually caved until, when they had the trench large enough for 24-inch pipe, it was some 10 feet wide at the top. They had put the hose on and had flooded the whole body. It is not necessary for me to tell you what weight must have been there after the water had run on it all day and all night.

Another case where I called attention to the party laying pipe, claiming that they were not back-filling as they should do, I was informed that they proposed to do it with a steam roller, and they did it, and the result was that the pipe did not stand the test.

The failure of the pipe is not always the fault of the pipe. Sometimes a failure occurs under the care of the engineer, but most of the cases are such as I have spoken to you about to-night.

Another point, which Mr. Baldwin has answered as well as I could possibly answer, is in regard to the burner. In the olden times it was customary to have one burner, and what Mr. Barbour

stated to you is practically true—that the kilns were usually in the hands of an autocrat, whose knowledge of the art was his capital, which he carefully kept to himself, and if he were taken sick it was necessary to shut down until he got well. But it is not the fact to-day. I think any large sewer pipe manufacturer would hardly dare be caught with one burner on hand. It is not an uncommon thing to have quite a number of men about the works that can burn a kiln and finish successfully.

The point was raised in regard to regulating the fire in the kiln other than by the eye and judgment of the burner. There are some questions arise that might possibly make it difficult to do that. You have all visited the sewer pipe works and seen the large kilns. The drafts are not always alike. The kiln will get hotter on one side than on the other, and it is the eye of the burner that generally regulates that by careful watching, repeatedly opening the kiln and slacking the fire. I am not sure, however, but that something of that kind will come about, but it does not seem to me, at this moment, as though it was hardly practicable.

In regard to the strength of pipes and sockets, Mr. Snow has stated to you the experience of manufacturers of socket pipe. A few years ago, Mr. Tidd called my attention to the matter of deep socket pipes, asking me if it were possible to make it, and I said that we were willing to try it and see if it was not practicable to make it. We had dies made, and found we could make it successfully, but it is a difficult pipe to make. We have explained that to many of you who have visited our works, and no doubt the Western manufacturers have explained it. It is a great deal more difficult than it would seem, but I never regretted having made deep and wide socket pipe. Before our friends in the West were willing to take up the manufacture of that pipe we made quite a good many miles of it, and furnished it to the New England cities, and are willing to be given an opportunity to continue the work. The question arose about the time we were well under way. (We had a combination—you all know what that is—but we have not got it now.) We had a combination, and there was one of our New England cities that advertised for deep and wide socket pipe. Then the question arose with the manufacturers of sewer pipe, as there was no regulation as to what the depth and cement space in the standard pipes should be. What constituted a deep and wide socket pipe? They commenced then to make a standard pipe that was about half-way between the deep and wide socket and the old standard pipe. That is the pipe that is being manufactured by most of the pipe manufacturers to-day.

Mr. Barbour touched upon the question of the price of double-strength pipe. I shall have to differ with Mr. Barbour there. I do not think the price is too high in proportion to the standard. The standard is not high enough, and the double-strength pipe is not a very easy pipe to make. It would take some time, and I would rather explain that to you personally, the difficulty in making a double-strength pipe. There does not appear to be any great difference between the standard and the double-strength pipe that would cause any inconvenience to the manufacturer, but it exists. We manufacture and sell all our pipe in New England, and we are catering to the needs of the New England trade. We are only too pleased to make and furnish double-strength pipe, but the price is not too high.

There are, as I said, other points in the paper which I might touch upon. What you people are aiming after is the improvement, if possible, of the sewer pipe which you people have to have to construct your sewers. I want to impress upon your minds that if it was really necessary to make a change to meet the views of the engineers in regard to the pipe, I do not know but what we should have to do it; but it is a large expense when you take the dies only. It means not $100 only, but a good many hundred dollars, to discard the dies and make any radical change in the shape of the socket.

Mr. President, I have occupied, I have no doubt, more time than should be allowed me, but I do want to say this: It is a great pleasure and privilege you have given me to come and meet so many of the engineers of New England, and if it is ever convenient for you to do so, I want to state to you that our works are always open to your inspection, and any suggestions that come from the engineers, I assure you, are appreciated by our company, and we extend to you all a cordial welcome to our works whenever you may find an opportunity to make it convenient to visit us.

Mr. B. W. Robinson, of Akron, Ohio.—I thank you kindly for the invitation to speak to you, but I do not know that I could add much to what has been said. I have been very much interested in the paper read, and, as has been said, we manufacturers want to keep in touch with the engineers and make the pipe best suited for the purposes for which it is used. The experiments of Mr. Snow in the line of deep and wide sockets are very important, as it has been the opinion of the manufacturers that that idea was a fallacy and practice would prove it undesirable. Deep socket pipe has given the manufacturers more annoyance than any other

idea that has come up. One engineer would specify 3-inch sockets, and another engineer would go ½-inch better, and another would perhaps specify 4-inch, thinking it was a good thing, and he would have more of it. Each specification requires a new set of dies throughout, which cost from $500 upward, and you can readily see that our shop would soon be filled with expensive dies and our stock of pipe would contain sockets of various depths. I think these experiments should not be lost sight of, and that we should derive some good from them by uniting on specifications which would be acceptable to both engineers and manufacturers as standard. It seems to me that it would be mutually profitable if the engineers and manufacturers would cultivate a closer relationship by more frequent meetings and exchange of ideas on the subjects in which we are each interested. I thank the Society for the opportunity it has given me of listening to the remarks this evening.

Mr. E. M. Buel, of the National Sewer Pipe Company, Barberton, Ohio.—I came here to-night prepared to make a very good speech and to instruct you in the manufacture of sewer pipe, but, being the last one called upon, I am very sorry to say that my friends and competitors have taken all my speech and left me nothing to say.

The manufacture of double-strength pipe has not been touched upon very thoroughly. Mr. Winslow spoke of it as being difficult to make. There is no question but what he is right. Double-strength pipe, in the first place, must be thoroughly dry before it is placed in the kilns, and even then it must be burned very slowly and evenly. I think we might liken the burning (or baking, as it ought to be more properly called) of sewer pipe to the baking of bread. You can put it into the kilns and bake it hurriedly; the outside will be burned to a crisp and the inside will be dough. I think very likely that the pipe of which Mr. Barbour speaks was, in the first place, put in the kiln before it was thoroughly dried, and, in the second place, was not thoroughly or properly baked.

You are all aware that 24-inch double-strength pipe should be 2 inches thick, but some engineers are calling for this pipe 1¾ inches thick. We are now supplying a large contract for pipe of that thickness. Some engineers call for a pipe with a socket 3 inches deep, some 3½ inches deep, some 2½ inches, and so on, also calling for different thicknesses. As this question is one of vital importance to the manufacturer, I deem it of much importance that the engineers agree upon a certain standard, and, of course,

it would be advisable if they could agree upon a standard that will not require dies different from some that we now have. Of course, every factory is making, and has been making, pipe of so many different styles of sockets and so many thicknesses that they have got a varied assortment on hand. The matter of dies is an important one, as it takes considerable money to equip a factory with various dies necessary for the manufacture of different kinds of pipe.

The Western engineers are copying after their Eastern brethren to a certain extent, and what the Eastern engineers adopt the Western engineers, sooner or later, adopt. If you, gentlemen, could adopt Mr. Barbour's suggestion and settle on certain specifications, it would soon be done throughout the country, and the manufacturers could discard many of their old dies and make pipe of one length, one thickness and one depth of socket. In this way we could carry more of a stock of the different sizes on hand, and it would benefit the trade as well as the manufacturer, as at present there are so many different specifications out that to carry a sufficient stock of each kind would entail the tying up of too much capital. As far as our factory is concerned, we are at all times ready and willing to make any pipe that the engineers want, but pardon me if I suggest that I think the engineers should give us some little encouragement and some little protection. You want the best pipe that is made, and if a few of us go to the trouble to perfect our mode of manufacture and the expense of obtaining new dies for you, do you not think it but just and fair that we be allowed a little more money for our pipe, so that we can use more pains and inspect our pipe closer? If you could shut off some of the manufacturers whose pipe you would not use any way from coming in and knocking down our prices, we believe we could see our way clear to giving you better goods than we are now attempting to give you. I beg to state that our factory is open to the inspection of engineers at all times, and we should be pleased to see each and every one of you there. I beg to thank you for your attention and for the privilege of addressing you.

Mr. Freeman C. Coffin.—I have found Mr. Barbour's paper very interesting. The experiments seem to have been very carefully made and clearly described. They will undoubtedly prove a valuable addition to our knowledge of this subject. One of his conclusions, however, does not appear to me to be sustained by the experiments.

In speaking of the effect of the sheeting at the ends of his

experimental trench, Mr. Barbour said: "As no ranges or braces were used on the inside of the end sheeting, the recorded pressures must in every case be higher than those in a continuous trench, and therefore on the side of safety." In the third experiment described, or the one having the sides sheeted vertically and smooth on the inside, the percentage of pressure on the platform was from 68.6 per cent. with 1 foot of filling to 44.4 per cent. with 8.8 feet. This shows that the friction on smooth vertical sheeting reduces the pressure. In a continuous trench there would be no friction of end sections, and each pipe or section of piping would receive the pressure of the earth above it, undiminished by end friction, but diminished by the friction on the sides.

In the third experiment, where the trench was sheeted on sides and ends, if this sheeting just inclosed the platform, or a space 5 feet 2 inches by 3 feet 3 inches, as seemed to be the case, the area of the side sheeting would be to that of end sheeting in the ratio of about 1.6 to 1. If the effect of the side and end sheeting were equal for equal areas, of the total reduction of pressure, found by the experiments, of 31.4 per cent. to 55.6 per cent., the side sheeting would be responsible for from 19.3 per cent. to 34.2 per cent. and the end sheeting from 12.1 per cent. to 21.4 per cent., or the pressure in a continuous trench would be greater by the amount due to the end sheeting, or from 12 per cent. to 21 per cent. greater than those found in the experiments.

While this may be a wrong interpretation of the experiments, it is probably true that the friction on the end sheeting must have materially modified the pressures, and that those in the actual trench would be a greater percentage of the superimposed load.

Mr. Snow and Mr. Barnes have referred to the deep and wide socket pipe, and both implied that, on the whole, there was no advantage to be derived from the use of such pipe. They referred, I believe, to the experiments and paper of Mr. Barbour as supporting this conclusion.

As I understand the paper, the results of his experiments and his conclusions are decidedly in favor of the deep and wide socket pipe. I do not know just what dimensions are meant by Messrs. Snow and Barnes when they refer to standard and deep socket pipe. Seven or eight years ago, when Mr. M. M. Tidd first suggested deeper and wider sockets, the standard and only pipe an engineer could get for sewers had sockets that were about $1\frac{1}{2}$ inches deep and $\frac{1}{4}$ inch wide. This often resulted in a cement space not over $\frac{1}{8}$ inch thick. Practically entire dependence was placed upon overfilling, with almost the whole of the cement outside of the joint proper.

Mr. Tidd designed a socket, the dimensions of which are given in the following table:

Inside Diameter of Pipe.	Depth of Socket.	Thickness of Joint.
6 inch.	2½ inch.	⅝ inch.
8 "	2½ "	⅝ "
10 "	2½ "	⅝ "
12 "	2½ "	⅝ "
15 "	3 "	⅝ "
18 "	3 "	⅝ "
20 "	3½ "	⅝ "
24 "	4 "	⅝ "

As there was no theoretical basis from which to proceed in designing these joints, and no experimental data upon which to form a theory, it would be remarkable, indeed, if these dimensions should prove to be exactly the most desirable.

It should be noted, however, that the so-called standard sockets of to-day approximate to the above table more nearly than to the sockets of 1890. Mr. Tidd's suggestion has, I believe, accomplished this result.

From a careful reading of Mr. Barbour's description of the experiments on cement joints, and from his conclusions, I believe the following may be gathered:

Tight joints can be made with rather dry mortar, carefully rammed into joints deep and wide enough to admit of such ramming.

In joints as usually made in the trench the mortar is compacted only in the outer ½ inch sufficiently to resist percolation of water under a small head.

In such joints overfilling is desirable, and will reduce the leakage very largely.

No socket should have less than ½ inch of cement space.

In overfilled joints as usually made the shallow joint is as tight as the deeper one, but the latter will better resist the movement of the pipe before the joint is set.

The exact depth of the socket is a matter of judgment.

With the above I entirely agree. I strongly believe, however, that the necessary care should be taken to ram the cement into the joint itself rather than to depend upon overfilling, as there is great danger that the cement outside of the joint will separate slightly from the pipe and leave an open crack directly through the joint.

I have recently made a few joints by putting in the cement

and then ramming a gasket into the outer end of the joint. A joint is readily and easily made in this way: After the pipe is in position, put sufficient mortar in the joint at the bottom of the pipe to nearly fill it. Place the gasket in at this point and ram it in flush with the face of the bell; then fill the joint with cement, from the bottom toward the top, bringing the gasket into place and ramming it flush with the bell, or perhaps a little further in, until finally it is brought up and twisted together at the top and well rammed home. Mortar of almost any consistency can be used in this method. I found that it was easier to manipulate when about as wet as would naturally be used for overfilling joints. If there is an excess of water, the gasket will absorb it and will hold the mortar in place. These joints were broken apart and found to be perfectly filled. They were made with the pipe lying on its side, as in a trench. After the pipe was in position and the mortar mixed, it required from five to six minutes to make a 6-inch joint.

This is certainly the best method that I have ever tried of making a sewer joint. There is very little waste of cement. The gasket will prevent the water from washing out the cement, and greatly strengthen the joint against movement before the cement is set.

For joints made in this way I believe that $\frac{1}{2}$ inch is the best width. The depth of the socket should be about $2\frac{1}{2}$ inches for 6 to 12-inch pipe and 3 inches for larger sizes.

I believe that, in justice to the manufacturers and for the interest of their own clients, engineers should agree upon a table of dimensions. It would be still more desirable that this table be the standard and only table. Some compromise of individual opinion would be necessary.

I believe with Mr. Barbour that $\frac{1}{2}$ inch should be the minimum of width. The matter of depth is not so important. It is probable that some depth between 2 and 3 inches would make a satisfactory socket.

Mr. George C. Dunne.—In order that there may be no misunderstanding in regard to the cement joint in the *standard* and *deep and wide socket* pipes, it should be remembered that, a few years ago, the *standard* pipe allowed only from $\frac{1}{8}$-inch to $\frac{1}{4}$-inch cement joint, and this was all that was required by engineers' specifications.

When the late Mr. Tidd made the drawings for *deep and wide socket* pipe for the Portland Stone Ware Company, he called for [illegible]-inch cement joint on all sizes from 6 inches to 24 inches, in-

clusive. Since then the manufacturers have agreed to change the depth of sockets and cement joint on the *standard* pipe, so that it is now $\frac{3}{8}$ inch on all sizes from 2 inches to 10 inches, inclusive, and $\frac{1}{2}$ inch on the sizes from 12 inches to 24 inches, inclusive.

If I clearly understand Mr. Barbour's interesting address, he believes that it is necessary to have a cement joint of $\frac{1}{2}$ inch on all sizes up to 12 inches, and $\frac{5}{8}$ inch on all the larger sizes. The present *standard* pipe does not meet these specifications, but the *deep and wide socket* pipe does.

Mr. H. P. Eddy, Superintendent of Sewers, Worcester, Mass.—One of your members kindly forwarded me an advance copy of this paper. I have taken a great deal of interest in the matter, not only since I received the copy, but while the experiments were being performed.

Worcester is still using large quantities of cement sewer pipe, together with some of the glazed pipe, and I was very much interested to find out the strength of the cement pipe, in comparison with that of the glazed. Consequently, I asked Mr. Snow to make us a few tests, which he very kindly did. I found that an 8-inch vitrified pipe was about 18 per cent. stronger than the cement pipe; the 10-inch, about 20 per cent.; the 12-inch, about 25 per cent., and the 15-inch, 30 per cent., while in our oval sizes we found that the 14-inch-by-18-inch gave us 2792 pounds as the breaking load per square foot; the 12-inch-by-18-inch, 2750 pounds, and the $12\frac{1}{2}$-inch-by-15-inch, 2033 pounds. The tests are of interest in comparing the strength of the cement with that of the vitrified pipe.

One point which I am rather surprised to find comes out as it does in the experiments—and I am not quite reconciled to it, either—is that the breaking load, or rather what was termed the net pressure in Table 6, should increase from the depth of 6 feet, which appears to be the minimum. Take, for instance, column 3: the net pressure of the earth and the steam roller per square foot is 2080 pounds at 1 foot in depth; at 6 feet, 1300 pounds; while from 6 feet to 20 feet there seems to be a nearly uniform increase. It would seem to me that if the experiments had been carried on a little further and a little deeper than they were the curves shown in Fig. 3 would have run down beyond a fixed point, or at least they would have been simply horizontal lines parallel with each other. I am very much surprised at the increase of pressure beyond the depth of 6 or 8 feet. My own experience is that sewer pipes break nine times out of ten in shallow trenches, and not in the deeper ones. This is true not only of pipe sewers, but

of brick sewers as well. Portions of one line of sewer which would be 6, 7 and 8 feet deep would be cracked, while the same pipe laid further along 9, 10, 12 feet deep, or even deeper, would be in good condition, and I always believed it was on account of the extreme pressure put on the pipe due to the lack of protection from the small amount of material above the pipe.

There is one other point that I want to allude to, because I think that one of your members, Mr. Barnes, of Medford, has rendered a valuable service in suggesting the winding of the pipe joints with cloth. I think I am right in the source of the suggestion. The statement has been made several times to-night that difficulty is experienced with the cement dropping down or being knocked away from the joints before setting, and doubtless the cement shrinks away from the pipe before and during setting. The winding of the joints with strips of cloth immediately after filling with mortar I have tried and found very successful.

I was also very much surprised to find that joints made of Portland cement, after setting 18 hours, leaked more than joints made of Rosendale cement which had set an equal length of time. It would be interesting to know the brand of Portland cement used.

My experience in making joints is that the sand mortar is very much better than neat cement, because there is much less shrinkage. I think that with neat cement there will probably be a shrinking away from the pipes before the cement is thoroughly set, thus greatly increasing the leakage.

Mr. Barbour.—Column 4 of Table 6 was not obtained by experiments. It is merely the result of calculations. The brand of Portland cement used was Alsen.

Mr. Frederick W. Farnham (by letter).—During the period from 1850 to 1870, the lateral sewers and a few of the trunk sewers in the city of Lowell were laid with cement pipe, most of which was made in the city.

From 1870 up to and including the present year, salt-glazed clay pipe or vitrified sewer pipe has been used in the building of all sewers which are of pipe, and all sizes and many different makes have been used, including Scotch pipe (imported), Portland and a half-dozen different brands of Akron pipe. These pipes have been laid at depths from 4 to 24 feet, in every kind of soil and under every circumstance that could possibly arise in a large city, and until 1895 all have been satisfactory.

In 1895, trouble was experienced in certain parts of the city, especially after showers, when the sewers would not carry away

the water delivered into them from the street catch basins. Knowing full well that the sizes and grades were such as would warrant the carrying off of all surface water that might fall upon certain areas, an investigation of the sewers which gave trouble revealed the fact that a 12-inch ring pipe sewer, built in 1878, and a 15-inch bell pipe sewer, built in 1878, had, although carefully laid by experienced city men in the first case and by a contractor in the second case, became so filled with tree roots as to reduce the carrying capacity of said sewers to that of a 2-inch pipe. I am of the opinion that a ring pipe and an ordinary bell pipe can only with great difficulty and exceeding care, under most favorable circumstances, be so laid as to exclude tree roots, and one single spray of root having gained an entrance into the sewer, it is only a question of a short time when the sewer becomes clogged and of no use. Such has been the case in Lowell, and, after mature deliberation and consultation, City Engineer Bowers decided to rebuild the before-mentioned sewers with deep socket pipe, laid with a gasket joint; the joint composed of, first, a layer of cement, then oakum and again cement, the whole made watertight; and, in fact, during the present year nothing but deep socket pipe has been used, in sizes above 10 inches, and 9188 feet of 12, 15, 18 and 24-inch pipe have been laid. At the time of writing there is being constructed several sewers in close proximity to the City Water Works conduit, which is of brick and from 20 to 40 feet below the surface of the ground. It is imperative to save the conduit harmless from contamination by sewage, and, as the country now being sewered is a thickly settled portion of our city, extra care has been necessary in building sewers. To that end we have used exclusively extra heavy deep socket pipe, laid with a gasket joint, as before mentioned, and the sewers are being laid at a depth of from 9 to 24 feet, and we feel absolutely certain that we are safe, not alone from leakage and infiltration, but also from breakage of 440 feet of 18-inch deep socket, double-thick pipe, laid 24 feet deep in sand excavation over and across said water works conduit.

With these few thoughts and observations favoring deep socket pipe, I will speak of pressures that have come under my observation.

Of the 50 miles of pipe sewers in the city of Lowell, in sizes from 6 to 24 inches and from 18 inches to 24 feet in depth, practically every one has been subjected to pressure from a 15-ton road roller, as well as the constant traffic of heavy corporation teaming, also electric and steam cars, and the first broken sewer

pipe has yet to be found in the city of Lowell. Let me particularize: In 1892, the Lowell and Suburban Street Railway Company erected in the western part of our city a very large power-house and car sheds, built with brick on an extra heavy granite foundation, all of which granite was teamed into Lowell from Chelmsford or Graniteville, and at the time the street railway plant was in process of building a main sewer was being constructed in the street through which all the teaming was done. At a certain place in the street two 15-inch Portland pipes were excavated at a depth of 18 inches from the surface, these 15-inch pipes being a part of a culvert which had previously been laid across the street, and it is a fact that the two pipes excavated were not even cracked, although the average weight per load of stone teamed over them must have been two tons. Since the finding of said pipes at said depth, and subjected to the practical test referred to, we have never doubted the utility of laying vitrified sewer pipe, and at almost any depth. Further, let me say that at depths from 9 to 40 feet, all over the city of Lowell, is found a strata of marl, very fine, and when mixed with water it forms a quicksand difficult to handle, and many times, in laying sewer pipe in this quicksand, we have excavated a few inches below grade and filled in with cinders, upon which pipes were laid, and never have we experienced trouble in so doing. Again, when in said quicksand and unable to get cinders, we have laid a piece of 2-inch plank, 6 or 8 inches wide and 2 feet long, across the trench, and laid pipes upon such ties with satisfactory results. I venture to affirm that in certain sections of our city conditions have existed as difficult to combat as are possible, and they have been met with never a break or a slump, with one exception. In a part of the city known to be the very worst for sewer building or excavation of any nature a 12-inch pipe sewer was to be laid at a depth of 9½ feet. Upon a certain day two pipes were laid before leaving the work for the night, and in the morning neither pipe could be found, not even with a bar. At first we thought of driving piles in the trench, but that meant time and expense, and we finally concluded to use gravel from a bank not far away. Accordingly, teams were loaded with gravel and hauled to the sewer, load after load, until nearly 100 loads were dumped into the trench and went "out of sight;" but "there came a time one day" when the gravel did not disappear, and after a few days' settlement, there being no change, pipes were laid as ordinarily, and all has been well ever since, for 10 years.

I might go on giving illustrations in our experience to prove,

at least to your contributor, that salt-glazed sewer pipe, as manufactured at present, is practical and wonderfully adapted to its principal use, and that *extra heavy* and *deep socket* vitrified sewer pipe fills a long-felt want with the city of Lowell.

MR. WILLIAM B. FULLER (by letter).—These experiments, both on the strength of sewer pipe, when subject to pressures similar to those sustained when in actual use, and on the actual pressure transmitted by earth refilled into trenches, enter upon a field in which experimental research has been much needed, and on which there has previously been but little more than theoretical information. The apparatus used serves to indicate to other engineers that very valuable results may be obtained without resort to expensive methods, and each such successful adaptation of means to ends encourages others to devise similar simple apparatus, and, by experimental research on problems of especial interest to themselves, to add to the total of engineering knowledge, and thus make more inexcusable the wastes and risks sometimes observed in construction work.

Mr. Barbour says "the pipe were laid in the trench exactly as in practice." Were there three or four pieces laid and cemented together at the joints as in regular work, and, if so, how long were the joints allowed to set before testing? Was the pressure platform always the exact length of pipe, including bell, and how was the bell situated in relation to the platform? A plan or longitudinal section, showing pipe in place ready for breaking, would make this point clear.

Mr. Barbour presents a formula, $p = c\frac{t^{1.65}}{d}$, which, as he says, represents fairly well the *average* results of the pipe breakages described in his paper, but, as shown in the last column of Table No. 3, it exceeds the minimum breakages of some cases by over 70 per cent., and I am of the opinion that any such formula is of doubtful value, more especially as in this instance it takes a form not sanctioned by theory. If the formula was made up to fit the results given in either Tables Nos. 3 or 4, it must be unreliable, as errors have been made in the makeup of both tables by averaging the first powers of the thicknesses and the corresponding strengths, and in Table 4 the experimental strengths given are averages of averages.

Theory gives to this equation the form $p = \frac{ct^2}{d+c_1 t}$ c and c_1 being constants, and I should hesitate to change this form, unless a careful study of all the conditions of each experiment made it

necessary. In looking over Table No. 2. the great variation in the strength of individual pieces of the same lot is immediately noticed, such variation in some cases, as with the 10″ B, amounting to over 100 per cent. Averages of such widely varying results are apt to be very misleading, unless the conditions of each experiment are identical. Theory indicates, for instance, that the mere packing of the haunches so as to prevent an increase in the horizontal diameter of a pipe under external vertical pressure increases its resistance to cracking more than 100 per cent. Mere variations in tamping alone, therefore, might cause all the variations noted, while the resistance of the pipe material remained constant. Again, the statement that varying the amount of filling over the pipe from 6 to 18 inches made no differences in the pressures transmitted appears to be at variance with the results of the experiments on trench refilling recorded in the second part of the paper, and I should incline to the belief that careful observations would show that varying depths of this filling would produce variations in the recorded pressures. Any variations in burning undoubtedly give widely varying moments of rupture, even in the same lots, and this again would produce varying results. Before suggesting the constant in any formula for thickness, therefore, I should consider it necessary that the conditions—the tamping at the haunches, the percentages of the transmitted pressures, the modulus of rupture of the material of each pipe, and the influence of the bell of the pipe—should be carefully ascertained and allowed for. Only until after these disturbing influences are taken into account can we hope for a correct formula for strength of pipe, and I believe it will then be found to accord closely to the indications of theory.

The results of the experiments recorded in the second portion of the paper indicate very clearly that the transmitted pressures in recent refilling follow a general law; but the small number of experiments tried would hardly warrant any general conclusions, or an extension of such conclusions to other materials or to the pressures to be expected after the trench refilling has completed its settlement, and it is to be hoped that experiments will be extended along these lines.

There is an old proverb that "every tub must stand on its own bottom," and it seems to me that this must ultimately be the case with earth refilling, and that the entire weight of all earth vertically above must ultimately be borne by the structure beneath.

In relation to the use of concrete around pipes, it not only makes an immovable foundation, but if it is carried around the

sides, above the horizontal diameter of the pipe, in sufficient quantities it prevents the spreading of the haunches, and thus more than doubles the resistance of the pipe to cracking.

Mr. F. A. Barbour (by letter).—Mr. Coffin takes issue with my conclusion—that the recorded pressures in a sheeted box are probably higher than those in a continuous trench. In this he may be right. Theoretically, it seems reasonable that if the sides and ends, by friction, serve as abutments to the arch action of the cohesion of material, then the ends must have their proportionate effect, and a continuous trench must result in a greater net pressure than an inclosed box.

Something may be said, however, in answer to this conclusion. In the first place, the experiments seem to indicate that it is not the actual friction or rubbing of the sides which determines the net pressure. There is very little difference between the trenches sheeted and the trenches unsheeted, in the net pressure transmitted to the pipe.

If Mr. Coffin is right, it would seem that the net pressure in experiment No. 5—that in which the platform occupies the middle third of the trench—would have been greater than in experiment No. 2—that with smooth vertical sheeted sides. Experiment No. 5 was taken transversely, a continuous trench, as compared with experiment No. 2. It is to be remembered that the machine lost no water in these trench experiments, and there was no measurable settlement of diaphragm, when weight was on platform.

In experiment No. 5 the bottom of the trench beyond the limits of the platform settled probably more than the platform; the prism of earth resting on the platform had sides of newly filled earth, also capable of settlement, and yet the net pressure transmitted to the platform was 4 per cent. less than in experiment No. 2, with sheeted sides and ends. Moreover, while the percentage of weight of stones transmitted through 9 feet of earth in experiment No. 2 was 23.5, in experiment No. 5 it was only 19.0.

These were the grounds of my conclusion in regard to the comparative pressure in continuous trenches, and, while it may not be right, I hardly think that Mr. Coffin's objection can be figured out in the way he has done. While theoretically reasonable, I think that, practically, the cohesion which will be transmitted across the shorter distance to the sides of trench will be the determining factor, and while perhaps the pressure in a continuous trench will not be less than in a sheeted box, it will not, at all events, be as much greater as the comparative area of

ends and sides in experiment No. 2 to that of the sides alone would indicate.

In reply to Mr. Fuller, it may be stated that no pipes were jointed together and broken, single lengths alone being experimented upon. It is believed that a bell and socket joint, properly made and thoroughly backfilled and tamped, is stronger than the rest of the pipe, and needs no experimental proof.

The formula, which has been presented rather diffidently as a fair expression of the results of the experiments, may not be that sanctioned by theory. It, at all events, has the merits of simplicity, and, considering all the experimental difficulties enumerated by Mr. Fuller, it probably comes as near to the truth as would the more complicated formula mentioned by him.

Theory indicates that the strength is directly proportionate to some power of the thickness and inversely proportionate to the diameter. With this as a foundation, the formula presented has been made to express the result of the experiments, with due allowance for conditions, of which note was taken at the time of making test.

It is true that in some cases the breaking strength varied 100 per cent. in pipe of the same lot, but in these cases the departure from the average is usually more or less explained by the notes taken at the time, which, owing to the necessary space, were not published.

Mr. Fuller refers to the importance of the tamping of the earth over and around the pipe. This was fully realized and great care taken. The same laborer did all the work, and the same earth and tools were used throughout. It is believed that so long as the personal equation must enter into experiments of this kind better results, in this respect, cannot be obtained. As to the value of the formula, if it helps to more properly proportion the thickness of pipe to the diameter than is done at present, it may serve as a basis for the determination of standard thicknesses, which, it is hoped, for the sake of the manufacturers, will be agreed upon by engineers. It should be accepted until something better, based on experiment rather than theory, proves it to be wrong. Column 3 of Table 4, to which Mr. Eddy has referred, was obtained by adding to the figures of column 2 the net weight of steam roller, which, as indicated by experiments with the stones, would be transmitted to the various depths.

Mr. Manley's experience in rolling streets does not affect the value of this table. A comparison of the net pressure as given in column 3 with the breaking strength of the various pipes shows

that even with 1 foot filling all pipes less than 20 inches should stand, but with a very low factor of safety. House connection pipes, 6 inches in diameter, at depths of 6 feet would have a factor of safety of 4 or more.

It is undoubtedly true that many pipes are cracked that are supposed to be all right. In my own experience an accident in one place led to a more critical examination in other pipe, and cracks barely distinguishable to the eye were found. Had not especial interest been taken in the subject these cracks would probably never have been known.

There are certainly some conditions under which it is not safe to use standard pipe, and it is hoped that this paper may serve as an aid to judgment in deciding upon the danger limit.

A LEVEL OF YE OLDEN TIME.

By Otto von Geldern, Member of the Technical Society of the Pacific Coast.

[Read before the Society, November 5, 1897.*]

Instruments for measuring in horizontal and vertical planes have been in use for many centuries, and, although the mechanical construction of the earlier designs may appear very crude to us now, when compared with our modern instruments of precision, it remains a fact that they were built upon correct mathematical or physical principles, and it is astonishing how much has been accomplished with them. The accuracy of the instrument depends upon the man using it. This was as true in olden times as it is to-day; and, while the precision of the instrument has been brought to a marvelous state of perfection, we would find it pretty difficult to improve upon the man who, say even two thousand years ago, applied his science to the solution of practical geometrical problems of the day.

Hero—about 150 years before our era—was the author of a treatise on surveying, and the possessor of an instrument, perfected by himself, with which he accomplished results, by means of laying off right-angles, and on the principle of similar triangles, that may have been very accurate and must certainly have served the purposes for which they were intended.

One of the principal problems arising then, or in any subsequent century, must have been that of transferring a level from one locality to another. Existing engineering works of all ages proclaim this, and it would be interesting to us now to know with what precision this was accomplished and the nature of the instrument with which it was done. If we dwell for a moment on the extreme care and accuracy with which a modern Y-level is built, in which every attention is paid to the optical requirements, so that they shall harmonize with the fine mechanical features; and if we consider with what painful precision a glass bubble-tube is ground, and the extreme accuracy with which it may be made to operate, it seems almost impossible for us, who are used to such instruments, to conceive how any one could have run a line of levels without them. And yet it was done. It is certain that the earlier methods were incapable of the present refinement of results, but the artisan

* Manuscript received Nov. 23, 1897.—Secretary, Ass'n of Eng. Socs.

then was certainly able to turn the results to practical use; and this is all we can achieve to-day.

The plumb-line, which is normal to a horizontal plane at the point of the plumb; or a body of still water, which indicates a level surface, have always been the natural bases to which levels could be referred.

In the work of the great aqueducts, the Romans employed a rod or stick about 20 feet long, having at its extremities two legs, fastened at right-angles to it. Crosspieces were attached to the rod, upon which were drawn vertical lines that were adjusted to correspond to plummets suspended from the rod. Vitruvius describes such an instrument, called the chorobates. Of the three known methods of leveling, either with the dioptra, the libra aquaria or the chorobates, he considered the latter the most accurate and preferable.

It is interesting to read his suggestions regarding its use. He says: * * * "If the wind obstructs the operation of adjusting the plummets to the lines of the instrument, let a channel be cut on the top of the rod, 5 feet long, 1 inch wide and ½ inch high, and let water be poured into it; if the water touch each extremity of the channel equally, it is known to be level. When the chorobates is thus adjusted level, the declivity may be ascertained. Perhaps some one who may have read the works of Archimedes will say that a true level cannot be obtained by means of water, because that author says that water is not level, but takes the form of a spheroid, whose center is the same as that of the earth. Whether the water have a plane or spheroidal surface, the two ends of the channel on the rod right and left, when the rod is level, will nevertheless sustain an equal height of water. If it be inclined towards one side, that end which is highest will not suffer the water to reach the edge of the channel on the rule. Hence it follows that though water poured in may have a swelling and curve in the middle, yet its extremities to the right and left will be level."*

As it was manifestly impossible to transfer a level with this instrument to any considerable distance, it must have required a frequent repetition of stations in work where a certain degree of accuracy was called for.

The principle of creating a quiet water surface for leveling was applied for many centuries, the original form being improved

*From the "Ten Books of Marcus Vitruvius Pollio," Joseph Gwilt's translation.

until it became more compact and practical, like the old water balance, which many of us remember and have seen in actual use.

There were other principles resorted to, however, one being the suspension or support in its center of gravity of a long and heavy body—like a metal straightedge—which, when thus suspended or supported, would lie in a horizontal plane.

We have records of these contrivances that date back two centuries. Even at that time the level had become a measuring apparatus of considerable refinement, to which a number of accessories had been added; the application of glass lenses was not uncommon, although employed somewhat differently than to-day. A silken thread furnished the horizontal crossbar, which was placed in the focus of the objective lens and viewed through an eye-sight.

In the records of the scientific societies, as far back as the beginning of the eighteenth century, we meet with occasional references to this subject. It seemed to be the evident design then to extend the usefulness of the level so that it might be made operative for long distances without increasing the chances of error, the object being to facilitate the field work without destroying the accuracy.

It is the purpose of these preliminaries to call attention to a memoir, published with the papers of the Royal Academy of Paris for the year 1704; by Monsieur de la Hire, an astronomer, a prominent member and a man of many scientific attainments. That he was most active and fertile is shown by the fact that in the Transactions of the Academy there appear many other papers by the same author on the most diverse subjects, wherein the practical application of science appears to have been the principal object.

The memoir refers to the invention of a new level on the principle of fastening an iron rule at its center of gravity to an upright support canting on its base, the idea being that the rule, once properly adjusted, will always lie in a horizontal plane at the instant when in absolute poise, and indifferent to tipping towards either one side or the other. How he applies this principle to render it practically useful will be best seen in the inventor's description of it, to which attention is now called.

From the author's statements, it becomes evident that this level did not remain an idle invention, but that he must have tested and proved its utility in his work; he says that in a distance of 1¼ miles he was able to obtain a level to within 3 or 4 inches, and he adds that this is all we can hope for.

In this connection it would be interesting to know when all

these older levels were finally superseded by the telescopic level with the attached bubble-tube, for it seems reasonable to assume that from the time of the introduction and use of the bubble there could not have been any further need for the application of any other principle.

A description of the bubble-tube (libella) is mentioned for the first time in a small French pamphlet in 1666. The inventor appears to have been the mechanician Chapotot; but that it was not directly applied in the art of leveling for fifty years afterwards seems evident from the following memoir:

THE DESCRIPTION AND USE OF A LEVEL OF A NEW CONSTRUCTION, BY M. DE LA HIRE, NOVEMBER 12, 1704.

The great aqueducts which the ancients have made might have persuaded us that they were very skillful in the art of leveling, if the instruments which they used, and the whole artifice which they employed, had not been handed down to us in the works of Vitruvius.

The new discoveries that have been made in the Academy of Sciences, and the different levels that have been there invented with telescopes, which serve them for sights, have given us the means of making levels with a great deal more justness, and with much more ease, than all those which have been made till this time; since we may level at once a distance of 1000 toises without any sensible error.

We have in our hands the levels of M. Picard, Mariotte, Huygens, Thevenot and Roemer, whose construction were all different; and I have also given one which draws its justness from the surface of water, a description of which I have printed in M. Picard's treatise of leveling, in 1684, and which was afterwards copied in the memoirs of the Academy, in 1699. But the surveys that I have formerly made, by order of the King, in different places and at different times, for the space of about 100 leagues, have shown me that almost all these levels have great inconveniences in them, and that they cannot be easily transported without our being obliged to rectify them, and sometimes to restore the sights, which require pretty troublesome operations. Not that it is necessary to make use of a just level to make exact surveys, since we may easily arrive at it by taking some precautions, as is observed in M. Picard's leveling, and as I have explained it afterwards in a little treatise of leveling which I have given to the public.

The level which I here describe, and which I made some time ago, is constructed upon a different principle from all other levels

which have hitherto appeared, for they draw all their justness, either from the center of gravity of the body of the whole level, which is suspended upon a body flexible or otherwise, or from a plummet also suspended to a thread, as fine as a hair; or, lastly, from the surface of water, or some other fluid body, whose surface is always level. But this here is not at all suspended by any body whatever; on the contrary, the center of gravity of the body which serves it for a rule, as it does to many others, is placed above the point of support; so that if it was possible that the center of gravity of the body, which is a mathematical point, should remain immovable upon the support, which is the nicest point that it is possible to make, we should then have the true level, which would be the perpendicular line drawn to that which passes through the center of gravity and through the support. But as it is impossible to make the center of gravity stay in a fixed place above the point of support, we take for the true level the position where this point is indifferent to fall either on one side or the other.

It will perhaps be said that this principle is not so just as that where the heavy body is suspended by a flexible body; but if we make the least reflection upon these suspensions, we shall see that there are very great irregularities caused by the nature of these bodies; besides, if the whole machine is exposed to a little wind, it is in a continual shaking and agitation, and it is impossible to determine the level. I say nothing of the remedies that are brought to these shakings, as of plunging the weight suspended to the machine in water or oil to stop the vibrations, since even this remedy has great inconveniences, and yet is not sufficient.

This which I propose is firm, solid and steady, being once well-constructed; and it may be carried about as we please, without being afraid that it may alter; and if it makes any alteration, it will be very easy to rectify it without changing its place, or, as we say, a single station.

The new sights upon glass, as I have proposed them to the Academy, and as they are described in the memoirs of 1700 and in my astronomical tables, give it also a very great advantage above all the rest; for these sights are unalterable by all the changes of the air, and cannot be spoiled by any accident whatever, though they should be at least as fine and slender as the threads of a silk-worm, which have hitherto been considered as the most fit to make exact observations with. It is very easy to make them, since it is only a little line or very fine stroke marked with a diamond upon a little bit of glass, which is fixed to the focus of the object-glass of the telescope; for the center of the object-glass is in the room of an

object-sight, and the stroke upon the glass serves for an eye-sight. It is easy to judge that this eye-sight cannot suffer any alteration or change, either by heat or cold, by little insects which fix themselves to the silk, by touching it, or, in fine, by carrying the instrument in any manner whatever; for it will be as solid as the object-sight.

The principal part of this level is an iron rule, which bears at its extremities the sights or diopters, which are an object-glass of a telescope for the object-sight; and for the eye-sight, a little bit of glass with a little stroke, as I have just said. This glass runs in a frame or groove, that it may be stopped at what height we please. This rule is instead of the body of a telescope, which has no eye-glass, and has no other tube than the whole box which is blacked on the inside and well closed.

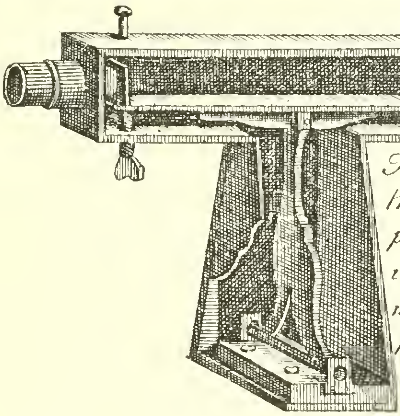


Figure of the Level proposed in its box with the fore part removed

There is, under this iron rule, another rule placed upon the ground, which serves to make it more firm, and has in the middle another piece of iron or brass about two-thirds of the length of the first, with which it is in a square. This piece increases in width at the bottom, so that the breadth is perpendicular to the length of the rule of the telescope. At the extremity of this piece are soldered on both sides the pivots, upon which the machine moves; and consequently as the whole body of the level is moved when the pivots are pretty near upon a level, the telescope rises and falls in its motion.

There is a little care required in the construction of the pivots. Their cut must be in form of a very acute lozenge, with a sharp point both at top and bottom; for it is by these places that the whole level is sustained upon the support.

The pivots are of tempered steel, and the place where they

bear upon the support is a little hollow, although sharp, that in the motion of the level they may not get from either side. There are two similar cavities opposite to one another, for an use which we shall hereafter explain.

The supports are fastened with screws to a particular piece, which is of wood, and this piece is held in the bottom of the box with screws, in such a manner that it may be drawn out of the box with the whole level which rests upon its supports.

These supports are made of a flat piece of tempered steel, in which are two round apertures, of which the inner one is blunted, to sustain the pivots of the level and to be firm enough not to spoil in the motion of the level.

The box that incloses the level may be made of what figure you please on the outside; but the whole level being of the figure of a T, the box ought to be pretty near of the same figure; and it must hold the instruments in such a manner that it has only liberty to move a little on each side. At the two extremities of the upper part of the box, which is the transverse of the T, there are two round covers, to one of which is fixed the end of the tube where the porte-oculaire enters; for the eyeglass is not fastened to the telescope, and we may by this means bring it nigher or farther from the eye-sight, according to the strength of the observer's sight. The aperture of the other end of the box serves to let the rays of the object pass, which meet the object-glass or object-sight.

Toward the eyeglass at the lower part of the length of the box is a pretty long screw, which moves in a nut fixed to the box. This screw serves to raise the end of the iron rule as occasion requires. The furrows of this screw are very fine to raise the rule, as it were, insensibly by turning the screw.

Opposite to the screw; that is, in the top of the crossway of the box, there is within a very slender spring, which is held to the box by the extremity farthest from the eyeglass; and at the other it bears a peg with a button, which passes to the outside of the box. This peg serves to drive the spring downwards, for in its natural state it is applied against the top of the box on the inside.

There is at the screw a repaire, or mark, to let it into the nut just in this place; and then the rule of the telescope being rested upon the screws, the telescope is over against the apertures of the box.

There is then nothing to be done but to place the sights so that their true line be perpendicular to the plane which passes through the center of gravity of the whole level, and through the line of the supports, and this is called rectifying it; and as all the

parts that compose it are solids, being once well rectified, it will not afterwards change; wherefore it is sufficient to rectify it well in constructing it by some of the ways which are explained in M. Picard's treatise of leveling, by establishing two points of level, and also with the level without being rectified.

TO RECTIFY THE LEVEL.

Supposing then that we have two points of level, A and B, about 100 toises distant from one another; we place the telescope at one end of these points as A, and point it toward the other point B, raising or sinking the body gently. And when the object B appears upon the eye-sight, if the rule of the telescope is placed upon the point of the screw, and it is not in a state of falling forward; that is, towards the object-glass, which we may know by pushing or raising the rule a little by turning the screw; for then the telescope falls lower, and is also placed upon the screw. This shows that the part of the whole level, which is toward the eye-glass, is too heavy; therefore the part of the rule toward the object-glass must be changed by means of a little weight which shall run upon the rule, and may be stopped in whatsoever place we please with a little screw, or only charging it with a little soft wax and lead. We charge this part of the rule so much that the sights, being pointed toward the object B, are indifferent to rest upon the point of the screw, or to fall forward, and then it will be rectified.

But if at first the sights being pointed toward the object B, the rule cannot keep upon the screw; we shall know by that that the part of the level toward the eyeglass is too light, and then it must be charged, as was done in the other case, till the level is in an indifferent state of falling or resting upon the point of the screw; and then the level will be rectified.

We might also, instead of charging the rule on either side, raise or sink the eye-sight in its frame, till the level was just, which we might do if the level is not far from being just.

We shall observe that in these operations every time that the telescope falls forward it is replaced upon the point of the screw, by pushing the spring at the top of the box, which drives the frame of the eye-sight downwards, and by that means replace the rule upon the point of the screw.

As this level may be put in a reverse situation, which is when the telescope is below the pivots, we must explain what ought to be observed in the constructing of it to serve in this state.

It is certain that if the pivots were a mathematical line, when the level is reversed it would point to the same place where it

pointed in its right situation, provided that this place was perfectly level with the place where the level is situated; and to rectify it we need only aim the telescope at the same point in the two situations of the level, by increasing or diminishing by degrees the weight of one of the ends of the rule. But as the pivots must have a considerable thickness to make them solid, it may happen that the plane, which passes through the center of gravity of the whole level, and through the line where the pivots rest, will not be the same in the two situations of the level; it must be rectified in the reversed position, the same as in the right. But as we must not change the sights which are rectified for the right position, we must correct the place of the pivots where they bear upon the support in the reverse position.

The level being therefore reversed, if the sights do not give the same point as in the right situation rectified, the pivots must be filed a little to drive the point toward the object-glass, if the sights fall too low in the reverse situation, or toward the eyeglass if they rise too high.

The pivots may also be made in another manner, so that the plane which shall pass through the center of gravity of the instrument, and through the place where the pivots rest, shall be the same, both in the right and reversed situation of the level; and thus we may rectify this level from a single station, without having a line of level.

In this second manner the pivots must be cylindrical, and very well turned and polished in the places where they bear upon and touch their supports, which ought to be a little hollow, like a pulley. Besides, the bottom and top of the hole of the support which sustains the pivots must be almost in a right line, that the pivots may not touch sensibly but in one point.

It is evident that in this construction of the pivots the center of gravity of the level, and the line which shall pass through the places where the pivots rest in the two situations of the level, will be always in the same plane, which shall also pass through the axis of the cylinder of the pivots.

This suspension of the level is not so nice as the first, because the place of the pivot, where it touches upon the support, is of circular figure; and in the first it is of a pointed figure, a little blunted.

THE USE OF THE LEVEL.

To make use of this level we must first put the screw to its mark, that the sights may be over against the apertures of the box. Afterwards, by means of the springs, we drive the rule of the tele-

scope against the end of the screw, in such a manner that it does not fall from the other side, which is easy to do by inclining the box; and in this state the rule of the telescope, being placed upon the screw, without the spring holding it, we bend the box by degrees toward the end, where the object-glass is, till the telescope falls on that side. Then we hold the box as firm as possible in this state, either upon a foot or against some other solid body; the telescope must be then pointed toward the object that we would level, and we ought to observe exactly the part of the object that appears upon the stroke which serves for an eye-sight. But as I suppose the telescope to be placed upon the screw, we must push the screw gently till the telescope falls on the other side, and observe well the part of the object which appears upon the stroke when the telescope falls; and to be assured of it, we must drive back the telescope upon the screw by means of the spring, and observe if it falls again; and if the same object appears upon the stroke of the glass which appeared there before, we should then undo a very little part of the screw and, driving back the telescope upon the screw, observe what difference there shall be between the object which shall appear upon the stroke in this state of the telescope and that which appeared there before. It must also be considered if the telescope rests then upon the screw, or if it falls again from the other side; for to have the point of the level just, the telescope, being placed upon the end of the screw, must be in a state of falling on the other side without falling, and we cannot raise it the least with the screw without its falling; it is then that the object, which appears in the telescope upon the stroke of the sight, is in a level with the stroke of this sight.

What I say of the level must always be understood of the apparent level, with the relation to the place where the instrument is, which serves to level, as it is explained in the treatise of leveling; for to have the true level corresponding to that where the instrument is placed, we must make the correction to the apparent point of level, with relation to the distance between the place where the instrument is and the point leveled; but we do not here treat of this practice of leveling.

One of the advantages of this level is that it may be reversed and serve again to level in this situation without any preparation or change, and though it has then some vibrations, they last but a little while, for they come only from the body of the instrument, and not from the motion of the box, which must be held firm, but without any subjection, since it loses nothing of the justness of the level; we may also easily stop the shaking of the level by support-

ing gently the spring against the frame of the sight, and by letting it afterwards replace in its natural state.

The size of this level is not at all determined, for the greater the telescopes are the more distinct the distant objects will appear; but it will be much more inconvenient to be carried about.

I have proved that one of these levels, whose height and length was but 10 inches, determined the level to near 3 or 4 inches at a distance of 1000 toises (6400′), which is all we can hope from a level, since an object of this bigness, at this distance, is entirely covered by a single thread of silk.

We may make use of different supports, but one of the most convenient ways for practice will be to fix the box of the level very firm, with a screw, against the cross of a painter's easel, which is solid; we might also hold it only in the hand, and bear it against some very stable body, whilst the operations are performed.

It must be observed that when we would transport this level, the pivots should not bear at all upon their support, which will be very easy if these pivots jut a little out of the box, and if there are in this place upon the box two sorts of hooks, which are engaged in the ends of the pivots and hold all the level raised out of the supports. We might also fix the telescope against the end of the screw by means of the spring, which shall be rested upon the sight; but if we would open the lid of the box we might engage the whole level between some brackets, which will hinder it from balancing on one side or other in carrying it a long journey.

DISCUSSION.

Mr. Adolph Lietz (Member Technical Society).—Mr. von Geldern's paper is of great interest; our engineers, accustomed to handle instruments of the latest improved style, ought to feel a certain amount of comfort in comparing a level of the olden times with a modern instrument.

The constructor of the level described places importance upon the adjustment, which can be effected without removing the instrument from its station, a feature preferred by our engineers to-day, for they generally demand the Y-level, which can be adjusted from one station. It appears that the reason for this preference is not well-grounded, as it is generally coupled with the idea that such instruments are capable of doing more accurate work than the Dumpy level.

Many engineers condemn the use of Dumpy levels without sufficient reasons. It is true that instrument makers in this country have not generally advocated the introduction of this old, use-

ful and, in Europe, more universally employed tool; but it must be remembered that the maker often meets with difficulties by introducing a new instrument or, as in this case, an old one, of which the professional engineer is not aware. If a Dumpy level is properly constructed, and if its mechanical and optical requirements are up to the standard, its principal advantage over the Y-level, which has lately come into general use, it makes the ideal of adjustments and reduction in price.

If the Y-leveling instrument is supplied with the reversion level, which has lately come into general use, it makes the ideal leveling instrument of to-day for the American engineer; for the reversion level admits of running true levels, regardless of the adjustment of the instrument, by a method of vertical double centering.

The idea prevails among engineers generally that a perfect adjustment of a Y-level can be effected from one station. This is not quite true. Even if the telescope collars are not of exact equal diameters and perfect cylinders, but if the Y's are both filed out to the same angle (this is generally the case, or at least very nearly so, as most makers file them out by means of gauges) it may be so adjusted that the bubble on all reversals in the Y's and revolutions on center will always give the same reading at both ends; that is, indicate a true horizontal position. To ascertain whether the instrument is true, however, can only be done by the three-stake adjustment,—except when a reversion level is adopted, as referred to before.

The reversion level can, with equal advantage, be applied to the transit, and it has already found a wide application in this capacity during the last years. While the reversion level is not new, its early application was prevented chiefly by its high price, which is reduced now by improved methods of production. Some years ago I was requested by Mr. C. S. Batterman, mining engineer, to construct a level for a transit telescope, which, according to his design, should revolve on its axis, and thus fulfill the duty of a reversion level; this was made and, I believe, has given satisfaction. The objection, however, will remain that adjustments which have to be provided are liable to change, and may need attention now and then; its cost, also, is higher than the reversion level, as applied to-day. The reversion level may also be applied with equal advantages in other directions.

I first adopted it in the capacity of a striding level for a high grade theodolite, built some months ago, and I believe that in time it will find a wider application for such purposes.

It is interesting to learn that the spirit level, now so universally applied, was not generally in use for leveling two centuries ago; and we have some reasons to consider this authentic from the fact that the author of the original paper just read does not refer to it; and we may take it for granted that the instrument and methods of the principal geometer of his time, Monsieur Picard, were known to him; and had Picard employed the bubble tube for leveling, or had he referred to it in his treatises, it is reasonable to suppose that de la Hire would have mentioned it. This is all the more astonishing since the spirit level was not entirely unknown, for it had been described as early as 1666.

I would like to branch off at this point, and, if you will permit me, I will make a few statements about modern surveying instruments from the standpoint of the instrument maker.

A prominent feature of a modern level or transit is the telescope. It is true to state that every advance in optical science has brought an improvement to it.

The requirements are power, definition and light. How to combine these best, and not increase the advantages in one direction without a loss in another, is the study of the instrument maker. And a very difficult one it is—and a thankless one, too,— for nothing is understood and appreciated so little as this particular feature, even among our best engineers, who often find fault where no fault can be proven. I am glad to have this opportunity to discuss this subject before the Society, and, while it may digress somewhat from the original subject, it will be of interest to you to learn what is demanded of a telescope to-day.

The introduction of the Jena glass was an achievement in the manufacture of telescopes for surveying purposes; and with the best material now on hand, it behooved the optician to make his lenses and lens-systems, and the instrument maker to study the conditions under which they had to be applied to furnish the best results in the field practice of the engineer.

I have had experience in this direction, and the statements that I shall make are based upon practical tests that I have had frequent occasion to carry on.

Assuming that the mechanical work of a telescope is of high order, and that the best lenses obtainable have been properly fitted, its capabilities depend upon the amount of light admitted and the magnifying power. An increase of power without corresponding increase of light is of no particular gain; and by using too low a power we do not get all the optical effect of a first-class objective. There must be a certain proportion between aperture and focal

length from which the most practical result might be expected. This matter has had the consideration of some of the most eminent opticians.

It is generally assumed, and we have practical reasons for it, that the best effect is obtained if an objective with a $1\frac{1}{8}$ inch aperture, having a certain focal length, be supplied with an eyepiece resulting in a telescopic combination of a magnifying power of 20. For instance, with an objective focus of 10 inches, the equivalent of the eyepiece should be $\frac{1}{2}$ inch. The $1\frac{1}{8}$ inch aperture will then admit the necessary amount of light.

The area of an objective with a diameter of $1\frac{1}{8}$ inches is nearly 1 square inch; by increasing the diameter to $1\frac{5}{8}$ inches the area is doubled, and twice the amount of light is admitted. It might now be inferred that the magnifying power could be proportionately increased, and that we should be justified in making it 40 instead of 20. Practice has taught us, however, that this is not applicable —that this light relation cannot be extended—and that a better result is achieved if we stop at a certain power and increase the amount of light instead. The reason for this is found in the disturbing influence of the atmosphere, which grows with the magnifying abilities of the telescope. Every floating particle in the air, and every motion and reflection of the light-wave is brought out so much more distinctly that a clear and well-defined image will become an impossibility; and the observer may be effectually brought face to face with the paradox that he will be able to see more and better with the naked eye than with a high-power telescope.

This accounts for the fact that telescopes are often condemned, that in reality possess excellent lenses, but too high a power; while others again are commented upon for their clearness that may possess very ordinary glasses. There is, therefore, a certain limit to the magnifying power of a surveying instrument that it is wise not to overstep, if we would retain a clear image. A practical ratio between focus and aperture is about 10 to 1.

Of two telescopes of even workmanship and the same focal length, the one with the greater aperture will show a clearer and better image. And in this connection it is well to notice the unexplainable fact of the existence of diaphragms within the tube to shut out the light. Why should this be resorted to when the necessity of light is so apparent? With a well-ground and corrected lens there is no need of placing any obstruction in the way of all the light it will admit. In faulty lenses there may be sufficient reason for such a course, but there is no excuse for using anything of that character in a modern telescope. Instead of

blinding a first-class lens, would it not be more reasonable to adopt a smaller lens, a shorter tube, and thus build a lighter instrument?

A telescope intended for tachymetric or stadia measurements must possess all the qualities mentioned to their very best advantage, particularly distinctness, in order that a graduated rod may be read long distances with the greatest possible accuracy. Correct determinations of distances are impossible with a poor telescope. The lenses should be of the Jena glass, accurately centered, and the eyepiece of the inverting form, which admits of the use of an objective of greater focal distance with the same length of telescope than the combination for erect vision.

In using the erect ocular, too much is sacrificed for what is only an apparent advantage, and I will go so far as to say that all good telescopes intended for tachymetric determinations should have the inverting eyepiece. That this form is not readily obtained in a manufactured surveying instrument in this country is not the fault of the maker, but is simply due to the fact that an unwarranted preference is given to an erect vision.

Assuming the focal length of an objective, f, as a constant (which it is, except for very short and inadmissible sights) the ratio between it and the distance between the threads s is the fundamental basis underlying this method of measuring, for f/s usually termed K, represents a constant by which any intercepted rod space must be multiplied to obtain the distance from the instrument to the road. We know that this refers to observations parallel to the horizon, and that it is customary to place the hairs so as to make the ratio 1 in 100.

In perfecting the optical features of an instrument, it was sought to obviate the necessity of correcting for the distance of the anallactic point. Since stadia measurements originate from the outer focus of the objective lens, and not from the center of the instrument, it becomes somewhat troublesome to apply a correction therefor on inclined sights, for, since the corrections remain constant for any distance and vary with the angle of inclination only, it is not practical to incorporate them directly into the tabular values employed in reducing stadia observations. Such tables are usually augmented by placing the corrections, due to what is generally termed the constant c at the bottom thereof. To overcome this difficulty, and to make every reading date directly from the center of the instrument, the Italian Porro invented a method in 1823, which is now beginning to be better known. This method has been frequently discussed. The *Journal of the Franklin Institute* contains an article in a number as far back as

1868. The *Engineering News* of November 8, 1890, has a short discussion by one of our best writers on these subjects, Professor J. B. Johnson, of the Washington University, St. Louis.

A convex lens of required focal length is inserted between the objective and the eyepiece, which transfers the anallactic point to the occupied center. Theoretically this is necessary, for the observed vertical angles have their common vertex in the center of the arc, or horizontal axis of the telescope; while the vertex of the diastimometric angle lies outside of the objective, a distance of 14 inches from the center of the instrument in the ordinary large transit. This would cause slight errors in vertical angle and distance, which disappear in the Porro telescope.

There are very substantial reasons, however, why this anallactic lens has not found a more general application in modern surveying instruments, for it is not a new thing with which we are dealing, but a principle that was known and used over half a century ago; and these reasons will now be briefly considered.

By inserting an additional lens the equivalent focal length of the objective is considerably decreased, and the power and capacity are thereby correspondingly lessened. To exemplify this, reference is made to an actual test of which the results were accessible to me. In this case the focal length of the objective equaled $13\frac{1}{2}$ inches, that of the inserted lens 5 inches and the distance between them $9\frac{3}{8}$ inches. The equivalent focal length of the combination was therefore $7\frac{3}{8}$ inches. The image of the system lay $2\frac{1}{4}$ inches behind the anallactic lens, and its distance from the objective therefore $11\frac{5}{8}$ inches. Here we notice that the available focal length has been shortened by the lens combination $4\frac{1}{4}$ inches, which is a direct loss of nearly 37 per cent. An ordinary telescope with a focus of $11\frac{5}{8}$ inches, possessing an eyepiece with one of $\frac{1}{2}$ inch, would have a power of 23; while the Porro telescope under similar conditions shows only 15, indicating the same perecentage of loss in power. There is, however, a slight gain in brightness with the same aperture of objectives, for the reason that the admitted light is concentrated in a smaller space. In order to make up for the loss in power, due to the anallactic lens, a more powerful eyepiece must be made use of. One with an equivalent focal length of 5-16 inch would about compensate the 37 per cent. of loss, but the brightness of the image would not then be quite up to that of the ordinary telescope, since the middle lens will cause a slight loss of light by reason of reflection and absorption. This, however, might again be rectified by giving the objective a somewhat larger aperture.

While it is readily seen that a Porro telescope might be constructed fully up to the capacity of our ordinary transit telescope, it is also apparent that much greater care and refinement would have to be resorted to to reach it, for it is very important that the entire mechanical work should be perfectly in harmony with the greater optical requirements. The tubes must be absolutely straight, the axes of the lenses must be identical and their principal planes normal thereto. Greater care must be exercised in the construction of the objective, it being necessary to correct therein for the aberration due to sphericity and achromatism of the anallactic—which is usually a simple convex lens—if we would retain a clear and distinct image.

It is a problem for the instrument maker to construct the Porro telescope so that there shall be no complicated parts, and no excess of cost to speak against it. The additional lens, whose focal distance depends upon the length of the telescope and the location of the center of the instrument, is placed in front of and not too far from the cross-hair diaphragm. Its distance from the objective must necessarily remain constant, and any motion of the latter in the tube must be made with the middle lens also. The lenses must move together.

It might be a more advantageous construction to adopt the movable eyepiece, and to focus by shifting the cross-hair diaphragm in connection therewith.

This lens combination has one peculiar advantage that must not be left unmentioned, which is that it requires but a very small telescopic slide movement to focus from long to short distances and *vice versa*. A range of half an inch may be sufficient to cover all the required lengths of sight.

In building the tube, provisions must also be made for readily removing the inner lens in order to clean it, which would probably be frequently required. The arrangements for this purpose must be so contrived that the lens may be replaced in its proper position and accurately adjusted to the required optical conditions.

Every feature goes to show that the mechanical work of such a telescope must be of the highest order, if it shall meet the demands made upon it. With the cheaper grade of surveying instruments a Porro telescope is an impossibility. Whether the extra cost necessarily connected therewith will be justified by the gain of the slight advantage in obliterating the constant c, is a matter that shall be left to your judgment. I am of the opinion that the smaller the number of lenses used in the construction of surveying telescopes the better will be the results, and the less the

structural refinement required to lead to them. Granted that we have a Porro telescope fully up to the power and capacity of that of the simpler construction, there are the constant disadvantages of using a powerful microscope, which must be more or less fatiguing to the eyes of the observer; and the accumulation of dust on the inner lens, a difficulty that may lead to considerable trouble and annoyance. These reasons have been more than sufficient to prevent the anallactic telescope from being generally introduced and practically used. It is granted, however, that, as a precise instrument, it is perfectly within the reach of the optical and mechanical arts to build one that shall fully accomplish the translation of the anallactic point to the center of the instrument.

From the beginning of the eighteenth to the end of the nineteenth century, what improvements have been made to furnish the engineer with a practical, useful and reliable tool for measuring. Compare de la Hire's level with one of your modern Y-levels. Compare his telescopic accessories with the refinements of to-day, which seek even to destroy the small anallactic difference in measuring distances telescopically, which could be so easily and readily corrected—if at all required—by a computed table or slide rule.

THE SHEARING STRENGTH OF WIRE NAILS.

A THESIS: BY FRANK BATES WALKER, FOR THE DEGREE OF CIVIL ENGINEER, AND CHAS. H. CROSS, FOR THE DEGREE OF MECHANICAL ENGINEER, UNIVERSITY OF MINNESOTA, MAY, 1897.

[Read before the Civil Engineers' Society of St. Paul, April 5, 1897.*]

AT the suggestion of Mr. A. W. Muenster, bridge engineer of St. Paul, the writers chose for their graduating thesis the subject of the shearing strength of wire nails. There appears to be but little record of research on this subject, yet the nailed joint or splice is a matter of everyday practice, and some definite knowledge of the action of nails in this connection would seem to be desirable.

Trautwine gives the only data on the subject found in any handbook. He says (on page 425): "Boards of oak or pine nailed together by from 4 to 16 10-penny common cut nails and then pulled apart in a direction lengthwise of the boards and across the nails, tending to break the latter in two by a shearing action, required about 300 to 400 pounds per nail to separate them, as a result of many trials." But this is not sufficiently specific to be of much practical value.

Experiments were made by Mr. F. W. Clay, C. E., Cornell, '93, on the shearing strength of nails, results of which are given in his thesis, entitled "Experiments to Determine the Holding Power of Nails and Drift Bolts." They were published, also, in *Engineering News*, January 11, 1894. Mr. Clay's experiments were made mainly to determine the comparative holding power of cut and of wire nails, pulling them out in the direction of the length of the nails.

His tests for the shearing strength seem to have been merely a side issue. We give, in Tables I and II, his experiments on shear. In regard to Table I, Mr. Clay says that he did not drive the heads of the nails up to a good bearing, but let them project a little, so as to get no effect of the head in the test. In Table II the nails were all driven the same depth into yellow pine and held on cleats of oak. The maximum pressure began soon after the cleats began to move. He does not state definitely, but he probably used cut nails only in Table II.

---

*Manuscript received November 29, 1897.—Secretary, Ass'n of Eng. Socs.

TABLE I (CLAY).

Holding power of wire nails and of cut nails subjected to a shearing strain.

Kind of wood, size, etc.	Size of Nail.	Stress per Nail.
Two slabs of 2-inch Georgia pine	12d. cut	950
" " " " " "	12d. wire	745
" " " " white "	12d. cut	905
" " " " " "	20d. wire	540
1-inch Georgia pine to 5-inch hemlock	20d. cut	870
" " " " " "	20d. wire	647
" " " " 3-inch oak	6d. cut	527
" " " " " "	10d. wire	526

TABLE II (CLAY).

Resistance to shearing stress by nails of different sizes.

Size of Nail.	No. of Nails.	Area in Wood.	Stress per Nail.	Stress per Unit of Area.
50d.	3	0.833	846	1015.6
20d.	3	0.580	533	918.9
18d.	3	0.566	490	865.7
15d.	4	0.471	375	796.2
10d.	5	0.427	452	1058.5
6d.	6	0.330	283	857.5

Prof. R. C. Carpenter made extensive experiments on the comparative holding power of cut and of wire nails, and the results were published in the "Proceedings of the American Society of Mechanical Engineers," vol. 16, page 1002, under the title of "Force Required and the Work Performed in Driving and Pulling Cut and Wire Nails." No results were found of tests on the present woods of construction and the larger-sized nails and spikes.

Having given a *résumé* of about all that could be found on the subject of shear, the writers will state briefly how they conducted their experiments and give the tabulated results.

About 300 experiments in all were made on the various sizes of wire nails, including a few on 7 and 8-inch square boat spikes. The primary object of the entire series of experiments was to determine the maximum allowable stresses which could be used in actual practice for the various sizes of nails.

The experiments were made as simple as possible. Two planed blocks were nailed together by one or more nails or spikes and then pulled in the same manner as above described by Trautwine. To facilitate the work, two clamps of ½-inch boiler plate, bent into U shape, were made to use with a small Olsen testing machine in the University laboratory. These clamps are shown

in position on the machine in Fig. 1. They are about 5 inches deep and about 6 inches square on the base. Two screws, with hand wheels, grip the specimens firmly and allow the pieces to be easily removed when tested. When the size of the nail required blocks larger than could be easily held, the clamps were not used; the ends of the blocks being sawed off square, they were placed between the pulling head and the weighing table of the testing machine, the load being applied the same as before. Care was taken that the pressure was applied directly through the nail and joint in both planes, in order to prevent any twisting motion of the pieces. In several cases where the first method was used the clamps held 2500 pounds before failing to hold the pieces. The entire holding action of the clamps was due to the

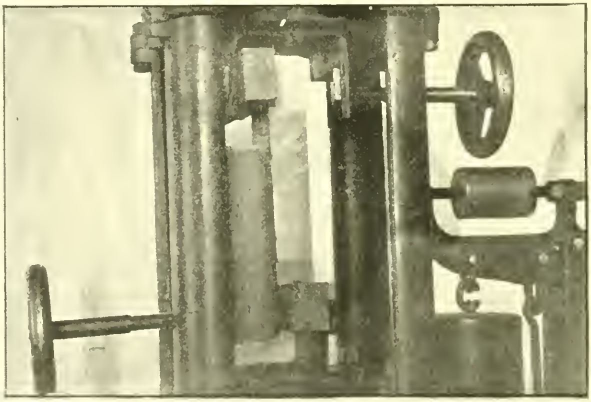


Fig. 1. Testing Machine.

friction and slight crushing of the test pieces between the screws and the sides of the clamps.

The length of the blocks and planks varied from 8 to 15 inches, and the width from 2 inches (when the 6-penny nail was used) to 6 inches (when the 50 and 60-penny nails and larger spikes were used). In only one or two cases did the planks split, and then the splitting was not due to lack of width. The thicknesses of the pieces experimented with were 1, 2, 3 and 4 inches, commercial sizes.

A lead-pencil line was drawn across the joint so as to indicate any movement; and later, when loads were read at the definite extensions, fine lines were drawn on the joint $\frac{1}{8}$ inch apart, and the extensions were read somewhat as with a vernier. By this means spaces could be read up to 1-64 inch, if desired, but nothing was noted nearer than 1-32 inch.

All surfaces in contact were planed, in order to eliminate, as far as possible, the friction of the joint. There was no space between the surfaces, the joint being closed up tightly to prevent unnecessary bending movement in the nails. The sizes of the nails used are given in Table III, together with the sizes as given in Carnegie and in Kent.

TABLE III.

Sizes of wire nails in the present experiments.

No.	Length.	Actual Dia.	No. per lb.	Dia. Carnegie.	Dia. Kent.
6d.	2″	.110″	196	.0808	.104
8d.	2.5″	.128″	109	.0935	.116
10d.	3″	.152″	64	.1082	.160
16d.	3.5″	.148″	60	.1285	.144
20d.	4″	.197″	29	.1620	.192
30d.	4.5″	.205″	25	.1819	.212
40d.	5″	.226″	17	.2043	.232
50d.	5.5″	.243″	13	.2294	...
60d.	6″	.261″	10	.2576	.276
80d.	7″	.303″	7	....	...
100d.	8″	.366″	5	....	...
	7″	.375″	Square, chisel-pointed boat spikes.		
	8″	.375″	"	"	" "

The wood was common Norway and white pine, sawed in 1896, and purchased by us in Minneapolis in March, 1897, it having lain in the lumber yard all winter. At the beginning of the experiments it was medium dry, but it became drier during the progress of the work, as it was in a steam-heated building. The oak was well seasoned and brittle.

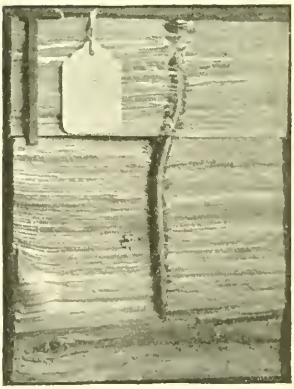
In each table are given the thickness and the kind of each piece of plank and each size of nail used. In every case the thickness of the block (or lower piece) was great enough to cover the point of the nail. No more than this was necessary, the width being sufficient to prevent splitting.

The figures in the column headed "Elastic Limit" (zero extension) indicate the loads at which the pieces begin to move past each other, or the point where the nail begins to bend and the wood to crush. It is not theoretically the elastic limit, for the wood and nail still retain some spring. If, after the pieces have moved 1-16 inch, the load which caused that extension be removed entirely, the joint retains enough elasticity to return practically to its original zero; but, if loaded beyond this 1-16-inch point, the joint returns only a part of the way when the load is removed. The column marked "Return Unloaded" gives this

30D. NAIL IN OAK.

40D. NAIL IN OAK.

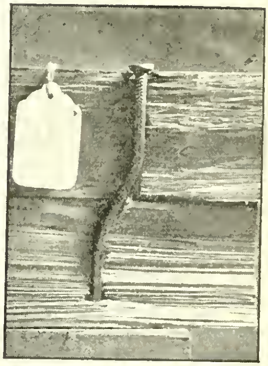
60D. NAIL SHORTENED TO 5¾ IN. IN N. P.



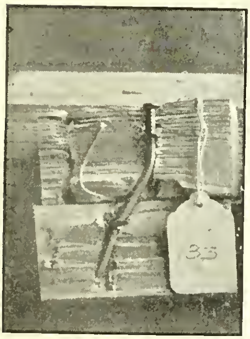
7 IN. NAIL IN N. P.

FIG. 2.

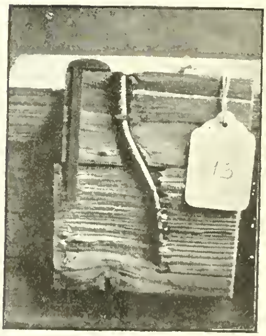
60d. Nail in N. P.



50d. Nail in N. P.

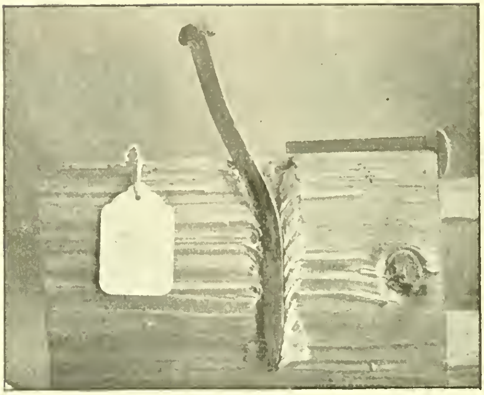


20d. Nail in N. P.

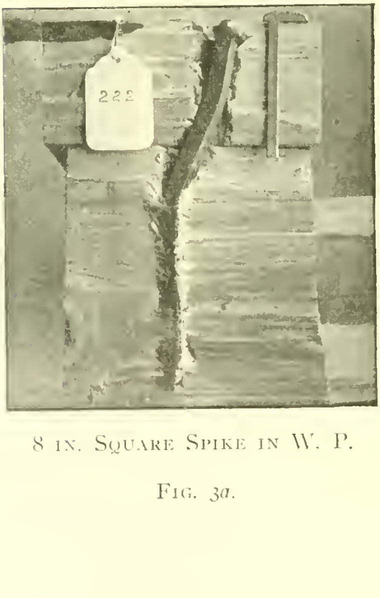


30d. Nail in N. P.

Fig. 3.



7 IN. SQUARE SPIKE IN W. P.



8 IN. SQUARE SPIKE IN W. P.

FIG. 3*a*.

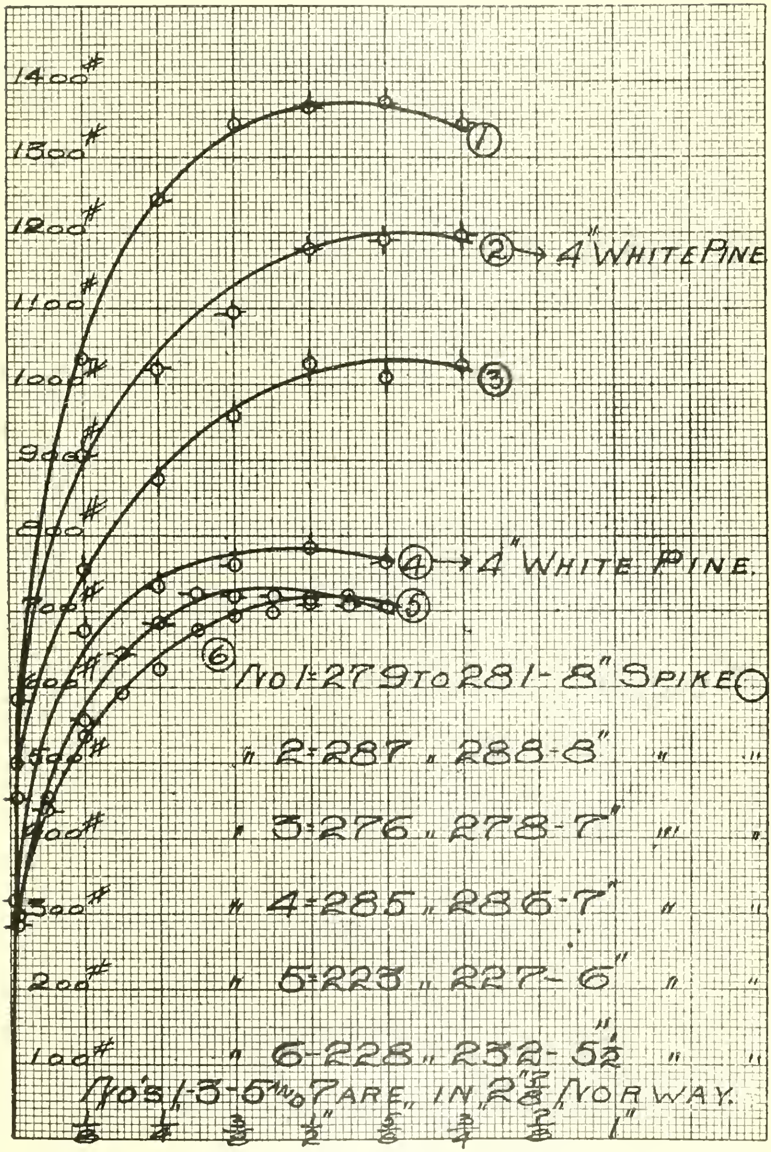


FIG. 4. EFFECT OF SIZE OF NAIL.

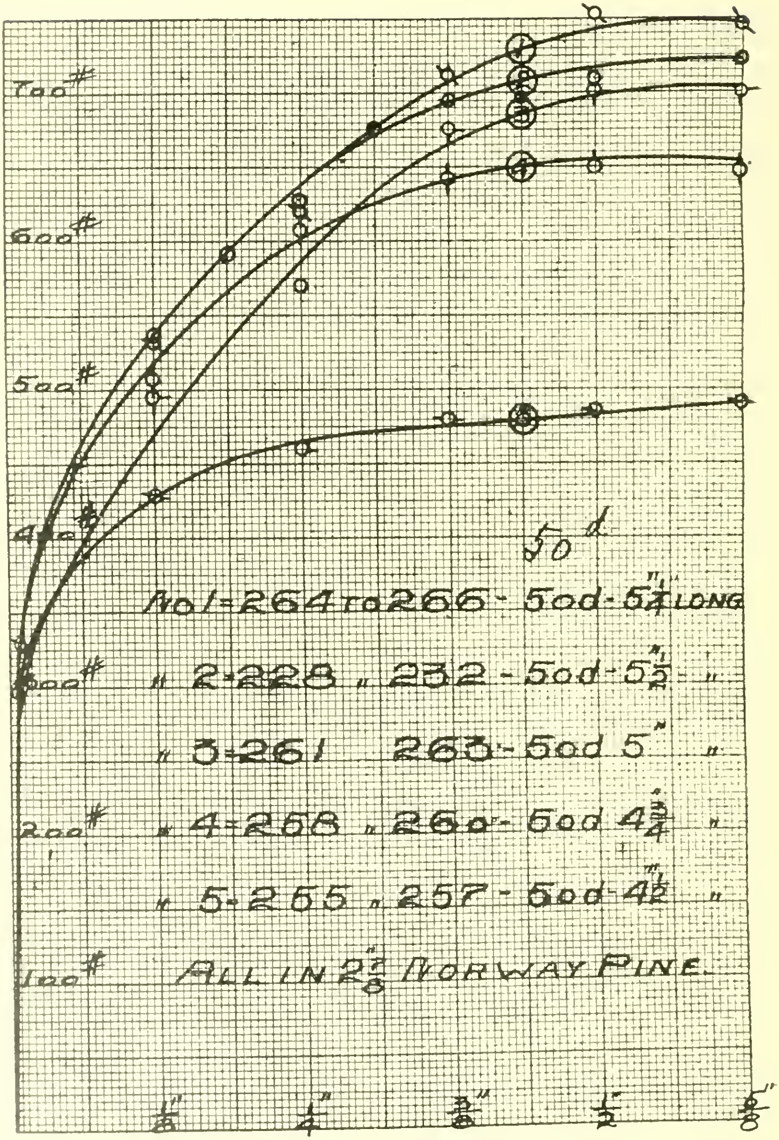


Fig. 5. Effect of Reducing Length of Nail.

distance after the maximum load has been applied and then removed. It shows, in some measure, the elasticity of the joint. If now a certain load or pressure causes an extension of $\frac{1}{8}$ inch, we find that when this load is taken off the pieces will return about 1-16 inch only by their own elasticity, it being necessary to apply a slight pressure in the other direction to return them to their original zero. The pressure being again applied, a small load is sufficient to bring them to the 1-16-inch point, and when that point is passed the load gradually rises to the amount supported at the $\frac{1}{8}$-inch point previous to the removal of the load. This action seems to be practically true for all sizes of nails and spikes. The action of the square spikes is by no means as symmetrical as that of the round ones. It will be noticed that the "Return Unloaded" and the "Extension at Maximum Load" are very nearly constant for all the nails, and that the elastic limit is practically one-half the maximum load.

All loads are given in pounds, and the extensions in inches or fractions of an inch. It was found that, after the load had been on a short time, the joint would not sustain as great a pressure as was required to move the pieces. This was probably due to a readjustment of the internal conditions of the joint itself. The various loads recorded in all the tables following Table IV and all tests on nails larger than 50-penny in Table IV were read about 30 seconds after the extensions had been made. This gave the joint time to make the most of its readjustment. The readings in the latter tables are from 10 to 15 per cent. lower than they would have been had they been taken immediately. This "settling" of the load continues during considerable time, but the maximum change takes place in the first half-minute. One time the test gave the following results: Three 50-penny nails, in $2\frac{7}{8}$-inch Norway pine plank, were subjected to a pressure of 600 pounds. In three hours the load had fallen back to 520 pounds (machine was not moved in the meantime), and in 48 hours the load sustained was 450 pounds, showing a fall of 25 per cent. Then the pressure was run up to 850 pounds (the elastic limit of the joint), and in five days the load sustained was 780 pounds, showing a fall of 8 per cent.

The square spike has the greater maximum strength, but a lower elastic limit, than the round wire spike.

A few experiments were made on 2-inch oak for comparison with the other woods.

The bends of the nails in the oak tests are very short and quite symmetrical. They vary in length in the 20-penny nails

Table IV. Single Nail Tests.

No. of Tests.	Size of Nail.	Timber. Through.	Timber. Into.	Elastic Limit. Max.	Elastic Limit. Min.	Elastic Limit. Mean.	Maximum Load. Max.	Maximum Load. Min.	Maximum Load. Mean.	Extension under Max. Load, inches.	Return Unloaded, inches.	Load Observed.
*10	6d.	1 in. W. P.	N. P.	100	50	71	180	120	149	1/8 to 1/2	1/32 to 1/16	Immediately.
†10	8d.	"	"	130	85	98	250	170	189	"	"	"
‡10	10d.	"	"	140	90	122	270	215	246	"	"	"
10	16d.	"	"	150	100	126	325	225	279	"	"	"
10	20d.	1 7/8 in. W. P.	"	250	185	220	480	400	431	3/8 to 1/2	1/8	"
10	"	2 1/8 in. N. P.	"	230	180	207	500	400	466	"	1/16	"
10	30d.	1 7/8 in. W. P.	"	300	240	262	500	420	476	3/8 to 1	1/8	"
10	"	2 1/8 in. N. P.	"	250	210	233	580	460	516	1/4 to 3/8	1/16 to 1/8	
10	40d.	1 7/8 in. W. P.	"	360	250	308	760	500	638	3/8 to 1/2	1/8	
10	"	2 1/8 in. N. P.	"	320	280	305	730	590	656	3/8 to 1/2	1/16 to 1/8	
10	50d.	2 13/16 in. W. P.	W. P.	360	300	347	920	725	800	1/4 to 1/2	1/32 to 1/8	30 seconds after extension.
‖10	"	2 7/8 in. N. P.	N. P.	530	320	413	1130	730	821	3/8 to 1	1/16 to 1/8	"
§5	"	"	"	310	280	298	740	640	710			"
10	60d.	2 13/16 in. W. P.	W. P.	350	310	334	860	760	815	1/4 to 1/2	1/16	"
**9	"	2 7/8 in. N. P.	N. P.	510	350	444	950	700	844	3/8 to 1/2	1/16	"
††5	"	"	"	360	200	282	800	650	730			"
2	"	"	"	430	400	415	940	870	905			"
2	7 in. ○ wire nail	2 3/4 in. W. P	W. P.	550	450	500	1020	980	1000	1/2 to 5/8		"
2	" "	4 in. W. P.	"	330	300	315	800	780	790	1/2		"
3	" "	2 7/8 in. N. P.	"	550	450	500	1050	1000	1030	1/2 to 3/4		"
3	7 in. □ spike.	2 3/4 in. W. P.	"	520	400	440	1930	1760	1845	1 1/4		"
3	8 in ○ wire nail.	"	"	600	550	583	1460	1260	1373	1/2 to 3/4		"
2	" "	4 in. W. P.	"	460	450	455	1230	1190	1210	"		"
2	" "	4 in. N. P.	N. P.	550	500	525	1370	1260	1315	1/2 to 5/8		"
5	8 in. □ boat spike.	2 3/4 in. W. P.	W. P.	600	400	470	2000	1830	1955	7/8 to 1 1/4		"

* For five of the tests, the elastic limit = 70 pounds.

† Two of the tests were in sap wood; elastic limit = 90 pounds.

‡ One test in sap wood; elastic limit = 105 pounds.

‖ In seven of the tests, the timber was highly seasoned, which accounts for the high resistance.

§ These tests were made to determine relation between load and extension (see Fig. 5), and elastic limit has possibly been taken at a somewhat lower point than the other tests. The maximum load shows, however, that the tests run low.

** Lumber highly seasoned.

†† Tests to determine relation between load and extension. Nail 1 inch from edge and 1½ inch from end of plank. Slight split in plank from driving of nail did not increase during the test.

from $1\frac{3}{8}$ to $1\frac{1}{2}$ inches for the same extension of $\frac{5}{8}$ inch. It is very interesting to note the relation between the hardness and thickness of the wood, the length of the nail and the resulting bend. The photographs also show the fibers of the wood as affected by the penetration of the wire nails, the round spikes and the chisel-pointed square spikes. To find what length of nail was necessary to develop the full strength, it was suggested that experiments be made on 50 and 60-penny nails diminished in length by regular amounts. This was done, and the results with 50-penny nails are given in Table V, Fig. 5. It is seen that the elastic limit is very nearly constant, but that the maximum loads fall off for the shorter nails.

TABLE V.

(See Fig. 5.)

Effect of length of nail.

No. of Tests.	Nails.	Through.	Into.	Length of Nail Inches.	Average Load at Extension of— 0	⅛	¼	⅜	½	⅝	¾
3	1-50d. wire.	2¾″ N. P.	N. P.	4½	320	430	460	470	486	490	480
3	1-50d. "	2¾″ "	"	4¾	307	507	607	643	650	646	
3	1-50d. "	2¾″ "	"	5	300	496	570	670	700	700	
3	1-50d. "	2¾″ "	"	5¼	333	533	620	713	753	743	

As might be supposed, the strength of a joint is directly proportional to the number of nails in it. To prove this, various experiments were made (see Table VI), using a varying number of nails. In regard to the number of nails in a given area, experiments were made, with the following results: With 50 and 60-penny nails in $2\frac{7}{8}$-inch pine, a distance of $1\frac{1}{2}$ inches from the end and 1 inch from the edge was necessary to prevent splitting; in the case of a 6-penny nail and 1-inch board, it required the nail to be $\frac{3}{4}$ inch from the end and $\frac{1}{2}$ inch from the edge to prevent splitting. Where the boards and planks were not split by the driving of the nail they developed the full strength; in other words, the nail sustained as great a pressure as though it were in the center of the piece.

Experiments were made to determine the elastic limit and crushing strength of the woods used (Table VIII). We also made an attempt to determine the elastic limit, modulus of elasticity and ultimate strength of the wire nails, but without much success. Several nails were broken, but not until they had been crushed in the jaws of the machine. Those broken averaged 90,000 pounds per square inch.

TABLE VI. EFFECT OF NUMBER OF NAILS.

No. of Tests.	No. of Nails in Joint.	Size of Nails.	Timber. Through.	Timber. Into.	Elastic Limit per Nail. Max.	Elastic Limit per Nail. Min.	Elastic Limit per Nail. Mean.	Max. Load per Nail. Max.	Max. Load per Nail. Min.	Max. Load per Nail. Mean.	Extension under Max. load inches.	Return Unloaded inches.
1	2	6d.	1 in. W. P.	N. P.			80			155	¼	$\frac{1}{16}$
1	3	"	" "	"			57			163	⅜	$\frac{1}{16}$
1	4	"	" "	"			50			156	⅜	$\frac{1}{16}$
1	5	"	" "	"			40			165		
2	2 & 3	20d.	1⅞ in. W. P.	"	233	225	229	455	433	444		
5	2 to 10	"	2⅛ in. N. P.	"	250	180	214	500	425	476	⅜	$\frac{1}{16}$ to ⅛
4	2 to 10	30d.	2⅛ in. " "	"	250	183	208	560	450	508	¼ to ⅜	$\frac{1}{16}$ to $\frac{3}{32}$
1	2	50d.	$2\frac{13}{16}$ in. W. P.	W. P.			305			795	½	$\frac{1}{16}$
1	4	"	" "	"			262			715	"	$\frac{1}{16}$
1	6	"	" "	"			333			750	"	$\frac{3}{32}$
1	9	"	" "	"			294			790	"	$\frac{1}{16}$
5	2 to 10	"	2⅞ in. N. P.	N. P.	450	320	375	960	700	854	½ to ¾	
4	2 to 6	60d.	$2\frac{13}{16}$ in. W. P.	W. P.	366	316	340	852	783	822	⅜ to ½	$\frac{1}{16}$ to ⅛
1	2	"	2⅞ in. N. P.	N. P.			350			815	½	
*1	3	"	" "	"			440			900	⅜	
1	4	"	" "	"			350			884	½	⅛
1	5	"	" "	"			380			930	⅝	
1	6	"	" "	"			383			1000	⅝	⅛
1	10	"	" "	"			380			970	⅝	
†1	10	"	" "	"			315			850	¼	
‡1	13	"	" "	"			346			723	½	

*Nail 1 inch from edge and 1½ inches from end of plank.

†Top piece slightly split before test. Nails 2 inches from end of plank.

‡Lower block slightly split before test.

These two last tests were taken at a time previous to the others in the serie.

TABLE VII.

Loads at different extensions through oak plank into oak block.

No. of Tests.	Nails.	Plank.	Average Load at Extension of— 0	1/8	1/4	3/8	1/2	5/8	3/4	7/8
5	1-20d. wire	2″	548	842	1126	1234	1366	1402	1408	1382
*5	1-20d. "	2″	528	792	994	1060	1122	1196	1252	1262
†4	1-30d. "	2″	578	913	1130	1193	1298	1378	1435	1478
‡4	1-40d. "	2″	683	1075	1380	1540	1595	1700	1793	1843
§2	1-60d. "	3″	715	1335	1690	1830	1890	2025	2085	

* Holes drilled with No. 15 drill, diameter = 0.177 inch.
† Holes drilled. Diameter of hole = 0.80 diameter of nail.
‡ Holes drilled. Diameter of hole = 0.200 inch.
§ Holes drilled. Diameter of hole = 0.211 inch.

TABLE VIII.

Crushing strengths of woods used—2-inch cubes with blocks whose length was four times the diameter; the elastic limit was approximately equal to the ultimate strength.

Wood	No. of Tests.	Crushing Load per Square Inch. Max.	Min.	Mean.
White pine	4	5125	4500	4844
Norway pine	3	6100	5625	5825
Oak	4	6825	6387	6603

In the light of these few experiments, it is rather difficult to say just what factor of safety should be used. The value given to each nail must undoubtedly be under the elastic limit. Possibly the results given above will aid in arriving at some definite ideas along this line.

DISCUSSION.

MR. K. E. HILGARD.—The daily newspapers report frequently the failures of grand stands, speakers' platforms and builders' scaffolds, which cause panic and too often the loss of human lives. These occurrences must necessarily reflect on the carelessness or incompetency and ignorance of builders and those who may have previously passed on the safety of such structures. The experiments brought before us, under a title which might possibly be attacked as a misnomer, tend to fill a vacancy and to supply knowledge in a direction in which, so far, decision has mostly been based upon practical judgment or rough guesswork. The average practicing builder, and even the engineer, is perhaps not afforded opportunity nor prepared to make tests or experiments for the purpose of increasing his knowledge. He must rely on precedents, and he is fortunate indeed if he can turn to some institution of learning and find some ambitious aspirant

20

to the profession ready to carry on investigation under practical guidance. The results before us, although not satisfying, are at least gratifying. All who have had occasion to make use of nailed or spiked joints in actual practice or mere design will fully appreciate the importance of the subject. While the character of the structures just mentioned is usually temporary, there are many cases, even in highway and railway bridges, where joints held by nails or spikes are called upon to transmit loads or strains for years and years and under greatly varying conditions. In view of this fact, it is much to be desired that the series of experiments be extended to cover a greater variety of timber used in construction, and to observe the results of repeatedly (suddenly or slowly) applied and released loads; the effect of age of joint in various stages of seasoning of the timber; the effect of water-soaking (once or repeated) of pieces joined, and possibly the effect of extreme temperatures. Like other conclusions to be drawn from experiments, they must be based on a great number of the latter in order to be of practical value. From the description of the manner of testing, it would appear that in the case of the blocks for which the clamps were not used the bending movement due to eccentric application of load was not entirely eliminated. However, results from tests including eccentric application of load properly analyzed and classified might prove fully as valuable, inasmuch as few cases occur in actual practice which are free from such a condition. The necessity of altering or elaborating the formulæ so far derived would undoubtedly appear, in order to cover a larger scope of practical utility. While the experiments can, therefore, not be considered to cover the question, they are decidedly interesting, meritorious and worthy of encouragement by the profession.

Mr. A. W. Muenster.—These records of experiments on the shearing strength of nailed wooden joints by Messrs. Walker and Cross will be received, I believe, with general interest by engineers.

Some years ago I commenced to look for data in regard to the shearing strength of nails in wood, and was very much surprised to find that practically no investigation had been made on this subject, which I considered one of some importance, and I wish to thank the gentlemen who have presented the above paper to our Society for their interesting work. Considering the limited time at their disposal, the main points within the given range of these experiments are very well covered. Future tests must determine the causes of differences, other than the obvious ones,

between parallel experiments. That these differences should be considerable was only to be expected where one of the materials of the composition—wood—is known to be of variable quality, not only within the same species and the same log, but within the same specimen at different degrees of seasoning. If I am not mistaken, the last condition will account for some of the greatest variations in the tests, and it is very desirable, if the experiments can be continued—as I hope they will be—that attention should be paid to this point.

The influence of the degree of seasoning is shown best, perhaps, in comparing the different tests of the 5½-inch and 6-inch nails.

The 3-inch and 4-inch planks used were, in the beginning, less thoroughly seasoned, presumably, than the thinner boards and planks used for the smaller nails, and the sustained loads were unexpectedly low in comparison. After several weeks the experiments were repeated, with the results shown in Table IV and in Table V. The materials used were, to all appearances, of the same quality as in the earlier tests of the same nails, but had, in the meantime, seasoned in a steam-heated room.

Another apparent cause of variation is the length of nail in the lower plank, a point that I shall refer to later.

In order to get immediately available results from the test for my own use, I have studied the experiments and tried to make some deductions.

The tests on the elastic limit and ultimate strength of the metal in the nails, and of the wooden specimens used in the experiments, were made for the purpose of discovering, if possible, some relation between these values and the shearing strength of the joint. On inspection of the test records, it is evident that some other quality in the wood than its resistance to compression in direction of the fibers determines the shearing value of the nail in it. While the tests of Norway pine show an ultimate crushing strength about 21 per cent. greater than that of white pine, there is practically no difference between the shearing of nails in either. The oak, with only about 36 per cent. crushing strength greater than that of white pine, gave a shearing value for the nail greater by from 110 to 130 per cent. This great difference is, no doubt, caused by the difference in structure between the woods. The pines are built up of alternate layers of hard and soft wood, permitting the fibers to yield more easily than the homogeneous fibers of the oak. That it is the quality of this soft fiber in the pines that largely determines the resistance is borne out also by

the statement of the authors that the nails seemed to have the same value whether strained along or across the fiber, and still farther evidenced by the slight difference shown by the nails in sap-wood. (See Table IV.) It will be necessary to establish a coefficient for each kind of wood by actual experiment.

The bend in the nails, after ultimate tests, shows great regularity in length and form. A number of measurements of these bends would seem to show a fairly constant relation between the diameter of the nail and the length of the bend, and this may be of some assistance in the construction of a formula giving the amount of resistance.

The experiments with the shortened 50-penny and 60-penny nails (see specimen No. 183, Fig. 3) show that, in order to get the full strength of the joint, the point of the nail should extend far enough into the under plank to prevent any sideway movement of the nail point and to develop the double bend in the nail, and that this will require a minimum length of from 10 to 12 diameters for white and Norway pine, less for the harder woods, and correspondingly more for softer and more porous timber.

The lack of this proportion will, I think, account for some tests considerably below the expected average.

Evidently the strength of this composite joint is made up of a good many elements—of the qualities, dimensions and relative arrangement of the materials—and it will take a much larger number of experiments and observations to discover the true relation of these elements.

However, in order to make the present experiments available for use, it is desirable to formulate some empirical expression that will give values for the varying diameters adopted by the different nail manufacturers, and that will conform approximately to the averages of the tests.

The formula Cd^2, where $d =$ diameter of nail in inches and C a coefficient derived from the experiment, would seem to follow the test values fairly well. For the point that we may call the elastic limit of the joint, for want of a better expression, the coefficient would be about 5500 for the white and Norway pine, varying probably from 4000 for green sap timber to about 6500 for thoroughly seasoned wood. The experiments on the oak timber show clearly how the hardness of the timber affects the strength of the joint, but is, I should judge, considerably above the average, as the oak was thoroughly seasoned and so hard that it was impossible to drive into it any nail above 20-penny size without first drilling a hole.

The coefficient for oak, as deduced from the few experiments, would be 13,500 for the elastic limit.

The following table gives the experimental value of the elastic limit averaged from all the tests, and also the corresponding values obtained by the formula suggested above:

Nails.	Length.	Diam.	Experimental Elastic Limit. Pounds.	Elastic Limit by formula $5500 \times d^2$. Pounds.
6d.	2″	0.11	55	67
8d.	2½″	0.128	88	90
10d.	3″	0.152	112	127
16d.	3½″	0.148	112	120
20d.	4″	0.197	218	212
30d.	4½″	0.205	226	231
40d.	5″	0.226	275	280
50d.	5½″	0.243	342	324
60d.	6″	0.261	362	373
80d.	7″	0.303	500	506

The tests show what might indeed be expected—that in a joint containing 10 or more nails each nail may be reckoned at its full value, and, what is of special practical importance, that 6-inch nails may be spaced $1\frac{1}{8}$ inches *c* to *c*, or about 4 diameters, and within the same distance to edge of timber, without impairing the strength of the joint. For the smaller nails this distance could presumably be reduced in proportion to the diameter.

The time test shows that there would be a certain extension of the joint under the load, called the elastic limit, after sufficient lapse of time, but this movement would probably not exceed 1-40 to 1-20 inch, and could hardly be considered of any moment in ordinary wooden construction.

What shall be considered allowable stress on such a nail joint will, of course, depend on the more or less temporary character of the structure, but from 60 to 80 per cent. of the elastic limit, it seems to me, would be a safe load.

It is highly desirable that these tests should be continued, and the experiments extended to other structural timber and to the larger sizes of wire nails, say from 7-inch to 10-inch.

BRADLEY & POATES, ENGR'S N.Y.

Association of Engineering Societies.

Vol. XIX. JULY, 1897. No. 1.

PROCEEDINGS.

Boston Society of Civil Engineers.

May 19, 1897.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 8 P.M. Ninety-eight members and visitors present.

President Dexter Brackett, on assuming the chair, thanked the members for the honor conferred upon him in electing him to the presidency for the coming year.

The record of the last meeting of the Society was read and approved.

Messrs. Frank B. Bourne, Ernest W. Branch, Ralph H. Chambers, Francis A. Dennette, John O. De Wolf, Charles H. Gannett, Herbert L. Ripley, Ernest W. Wiggin, and Herbert A. Wilson were elected members of the Society.

The Secretary read a short paper by Mr. Clemens Herschel, giving the history of the origin of the Chézy Formula for the flow of water in channels and conduits. A brief discussion of the paper by Mr. E. B. Weston was also read.

Mr. A. Lawrence Rotch, director of the Blue Hill Meteorological Observatory, was then introduced and read a very entertaining paper, entitled "An Account of the Meteorological Investigations in the Upper Air made at the Blue Hill Observatory." The paper was supplemented by a series of beautiful lantern slides showing the principal meteorological observatories of the world and the apparatus used at the Blue Hill Observatory.

The thanks of the Society were voted to Mr. Rotch for his interesting paper, and to him and Mr. H. H. Clayton for courtesies shown the members this afternoon during the visit to the Blue Hill Observatory.

Adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Club of Cleveland.

July 13, 1897.—Meeting of the Civil Engineers' Club of Cleveland, in the rooms of the Club, Case Library Building, Tuesday evening, July 13, 1897, President Ritchie in the chair.

Present, thirty-one members and six visitors.

The minutes of the last meeting were read and approved.

Charles O. Palmer and August A. Honsberg were appointed tellers to canvass the ballots for the election of new members.

The Executive Board reported the approval for active membership of Charles Warren Comstock and John William Easton.

Mr. William H. Searles reported as chairman of the Committee on Arrangements for meeting the excursion of the Ohio Institute of Mining Engineers, which took place on the 16th, 17th, and 18th of June.

Dr. Langley being absent, Mr. F. A. Coburn reported for the Committee on Annual Outing.

Mr. William E. Reed presented the paper of the evening, entitled "The 40-inch Equatorial of the Yerkes Observatory."

It was a very complete description of the great telescope and the observatory in which it is mounted, illustrated by half-tones from photographs taken during the erection and of the completed structure. An interesting discussion followed, in which Dr. Dayton C. Miller, W. R. Warner, and others took part.

Messrs. George Isaac Allen, William Sanford Bidle, Lord Mortimer Coe, John Nash Coffin, Charles Ithamar Dailey, Ernest Winfield Hulet, Arthur Cameron Johnston, Francis Henry Prentiss, William Emerson Schroeder, George Edgar Titcomb, and Rollin Henry White were reported as elected to active membership.

On motion, it was voted to adjourn to the September meeting.

After the meeting a light lunch was served.

F. A. Coburn, *Secretary.*

Detroit Engineering Society.

Detroit, Mich., July 23, 1897.—The regular monthly meeting was held at the Hotel Ste. Clair, Vice-President Alex. Dow presiding, and twenty-two members and two visitors present. The Executive Committee reporting favorably upon the application of A. B. Raymond, he was elected to resident membership. The same committee announced that the August meeting would be omitted, in accordance with a recommendation of the President, and noticed a by-law relating to dues of members joining the Society during the last half of the year, to be voted upon at the next regular meeting. The Executive Committee further reported that the Library Committee had submitted its report, and recommended that the work be continued by a committee of three. Upon resolution, the report of the Executive Committee was adopted, and the following committee was announced: Mr. Willard Pope, chairman, and Messrs. George Mattsson and Henry E. Whitaker. Five applications for resident membership were received and referred to the Executive Committee. The Secretary read a letter from United States Senator James McMillan, acknowledging the receipt of resolutions of the Society relative to the duty on foreign scientific works, and promising consideration of the same.

The Society then listened to a talk by Mr. George Y. Wisner on "Economical Engineering Construction," being a description of river and harbor improvement work on the Mississippi river and the Gulf of Mexico,

which led to a discussion, participated in by Messrs. Dow, Cooley, Dunlap, Williams, Keep, Hitchcock, and Wisner.

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

Montana Society of Engineers.

A SPECIAL MEETING of the Society was held in the G. A. R. Hall, in Helena, on June 26, 1897, to which the public was invited. The hall was well filled with an appreciative audience At 8.30 P.M. Mr. F. L. Sizer, chairman of the evening, announced Prof. L. S. Griswold, who would deliver a lecture upon the "Geology of Helena and Vicinity." Professor Griswold has spent the past year in examining and classifying the formations in the vicinity of Helena, and his work has been very thorough and complete. Specimens of different geological formations were shown the audience during the lecture. The lecture was illustrated by charts and lasted about one hour, after which Mr. R. H. Chapman, of the United States Geological Survey, was introduced, who delivered a short address upon what that department has done and is doing in Montana. The first surveys were made in 1882, and 16 sheets have been published, embracing 38,000 square miles. A party is now outfitting in Helena, which will extend the system of triangulations, after which topographical surveys will be made. Five parties will be placed in the field in different parts of the state. Mr. Walter H. Weed, United States Geologist, is now in the state and will remain during the season, engaged in geological work.

After the lectures a short business session was held, Mr. Finlay McRae presiding. Peter C. Kettle, of Belt; George R. Metlen, of Dillon, and Arthur W. Warwick, of Wickes, were elected members.

There were five applications for membership, which were favorably considered, as follows: Messrs. Frank Beach, S. H. Crookes, E. C. Kinney, A. L. Dean, and W. H. Williams. A unanimous vote of thanks was extended to the speakers of the evening.

A. S. HOVEY, *Secretary.*

THE regular monthly meeting of the Society was held in the office of Hovey & Bickel, in the Merchants' National Bank Building, Helena, July 10, 1897. Mr. F. L. Sizer was elected chairman for the evening. The minutes of the last meeting were read and approved, after which Messrs. Keerl and Taylor were appointed tellers to canvass the letter ballots. There were 30 ballots, all affirmative, and the President announced the following-named gentlemen elected members, viz: Profs. Frank Beach and W. H. Williams, of the State Agricultural College at Bozeman; Mr. S. H. Crooks, county surveyor of Park county; Mr. A. L. Dean, superintendent of the United Smelting and Refining Company, and Mr. Edward C. Kinney, civil engineer, residing at Manhattan, Mont.

Resolutions were passed that the members just elected and others that may be elected during the latter half of the present year be required to pay only semi-annual dues, in addition to the usual entrance fee of $5, and that they receive the JOURNAL OF THE ASSOCIATION for only the latter half of the year at the Society's expense, but if the Secretary is immediately notified he will order back numbers from the beginning of the year at the

additional charge to the member of $1.50. The Society, through the courtesy of Mr. John F. Davies, librarian of the Butte Free Public Library, is the recipient of a special index containing a list of books pertaining to engineering and architecture on file in said library. This list was prepared at the request of the Society at considerable labor by the librarian. The list shows 689 volumes of books upon engineering. Members of the Society in Butte were consulted and assisted in making the selection. The library doubtless has as choice and valuable selection of technical books upon this subject as any library in the West—in fact, as can be found in many of the large Eastern cities.

The Society tendered a vote of thanks to Mr. J. F. Davies.

Mr. Titus Ulke, of the United States Geological and Topographical Survey, gave a brief description of the work commenced and what is to be done during the present season in his department.

The Secretary was directed to make arrangements for an address by Mr. Louis Miller and an exhibition of his current water-wheel, a recent invention, which is attracting considerable attention. It was suggested that the Ten-Mile Creek, near the Broadwater Hotel and Natatorium, would be a good site for the exhibition.

Members are urgently requested to forward to the Secretary, to be placed on file, all articles pertaining to county surveyors or road legislation, or other engineering matters which may appear in the newspapers of the State, thus calling attention to matters which may be of importance and which otherwise would be frequently overlooked.

A. S. Hovey, *Secretary.*

Summer Excursion of the Engineers' Club of St. Louis.

On the afternoon of Saturday, July 17, 1897, the Engineers' Club of St. Louis, through the kindness of Mr. J. A. Ockerson, was invited to an excursion down the river to inspect the new Government dredge-boats now being tested at the lower end of the city. The steamer "Mississippi," with about seventy-five members of the Club on board, left her wharf shortly after 12 o'clock and proceeded down stream toward the point where the dredge-boats were operating. Immediately after leaving a delightful lunch was served. A stop was first made at the dredges "Alpha" and "Beta," which are now undergoing repairs on the west bank of the river. The general principle upon which all of these dredges operate is that of the centrifugal pump. The sand in front of the boats is first stirred up by water-jets, scrapers, or cutters into a sludge, and then pumped by a centrifugal pump through the boat and into a pipe leading from the rear end of the boat. This pipe is floated between pontoons, and may be adjusted to deliver the discharge at any desired point. The principle of the centrifugal pump is the essential one in all of the dredges, although they differ quite widely as to the details of the machinery. The "Alpha" was the first of these boats to be built. The "Beta" was the second, and is the largest dredge-boat ever constructed. It was guaranteed by the builders to have a capacity to handle 2400 cubic yards of sand per hour, but on test it handled 7400 cubic yards in this time.

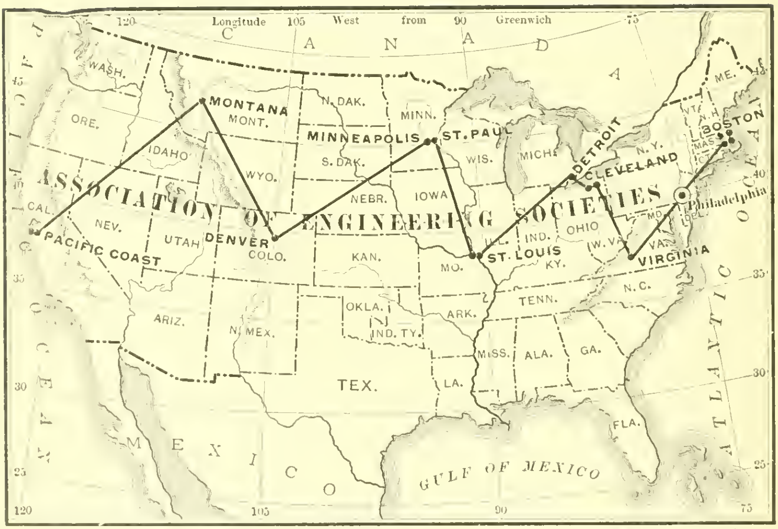
After these dredges had been inspected the "Mississippi" steamed to

the other side of the river, where the "Gamma" and "Delta" are now making their endurance test. Here the practical operation of the dredges was illustrated. The suction pipe was raised, and the methods of handling the different machines and the plans for anchoring the boat and for feeding the suction pipe forward were shown. One of these boats uses jets of water for stirring up the sand, and the other uses a revolving scraper.

A stop was next made at the snag-boats "Macomb" and "Wright," where methods for removing snags from the river bed were illustrated.

The day was an ideal one, and all who were fortunate enough to be on the steamer "Mississippi" thoroughly enjoyed the excursion. A vote of thanks to Mr. J. A. Ockerson, the host, was carried by a unanimous vote.

RICHARD McCULLOCH, *Secretary.*



BRADLEY & POATES, ENGR'S N.Y.

Association of Engineering Societies.

Vol. XIX. AUGUST, 1897. No. 2.

PROCEEDINGS.

Boston Society of Civil Engineers.

June 16, 1897.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock, P.M. President Dexter Brackett in the chair. Eighty members and visitors, including ladies, present.

The record of the last meeting was read and approved.

Messrs. George B. Francis and Alpheus M. Johnson were elected members of the Society.

The thanks of the Society were voted to the officials of the Boston and Maine Railroad for the courtesies extended by them to the members taking part in the excursion to the Middlesex Falls this afternoon.

Prof. C. Frank Allen then read the paper of the evening, entitled "Railroads: Their Development and Methods of Location." The paper was very fully illustrated by lantern slides, showing early as well as modern types of locomotives and cars, types of rails and rail joints and railroad locations in this country and abroad.

Adjourned.

S. E. Tinkham, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, Cal., August 6, 1897.—Regular meeting called to order at 8.30 P.M. by Past President Richards.

The minutes of the last regular meeting were read and approved.

Mr. George D. Blood, mining engineer, of Iowa Hill, Placer Co., California, was declared elected after a count of ballots.

The paper presented by Mr. James D. Schuyler and read at the June meeting by the Secretary, entitled "The Construction of the Hemet Dam," was reviewed by Mr. C. E. Grunsky and opened for a general discussion, which took up the evening.

It was moved and seconded that the Executive Committee be instructed to communicate with Professor Frank Soulé and to request him to obtain from the Board of Regents of the University of California the privilege of preparing all the available data of his college on Pacific Coast

Timber Tests into a paper, to be read before the Society and published with its transactions. Carried.

The Secretary thereupon read the reprint of a report by City Engineer Dockweiler, of Los Angeles, on the deterioration of the iron, cement, and brick work in the Outfall Sewer System of that city, caused by the accumulation of sulphuretted hydrogen gas in the sewer.

The Secretary was instructed to write to Mr. Dockweiler and to obtain from him further information and more of the facts and data regarding these ravages.

An excursion to Mt. Tamalpais having been planned by the Executive Committee, it was agreed that the committee appointed to arrange this outing have further time and report to the Directors any adopted plan for the purpose.

Adjourned.

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XIX. | September, 1897. | No. 3.

PROCEEDINGS.

Montana Society of Engineers.

In view of resolutions passed by the Society, March 13, 1897, a special meeting, to which all the county surveyors and county commissioners of the state had been invited, was held in the court house of Lewis and Clarke county, at Helena, March 30, 1897. John W. Wade, county surveyor of Lewis and Clarke county, called the meeting to order at 10 A.M.

ADDRESS BY JOHN W. WADE.

"The State Legislature, just adjourned, has given great prominence to the road problem by enacting laws radically changing almost every feature of previous regulations as to the maintenance of roads, and by this new departure county surveyors are now entrusted with the care of the entire system of wagon roads in the state.

"The average engineer may well fear the result of over-engineering, for it will be a very easy and natural mistake to apply too rigidly the principles of engineering to the maintenance of public highways; this is especially true of Montana at present because of the crude condition of our roads from an engineering standpoint. On the other hand, there is danger that, having found it impracticable, if not impossible, to use mathematical precision in many problems that will confront us, and despairing of ever securing professional order in the field and in the office, we will pigeon-hole our professional knowledge and 'go it by rule of thumb,' as road supervisors have done before us, with this difference, possibly, that we will use less common-sense.

"I think it can be easily shown that our greatest trouble,—to prove this law is a wise one,—will be in these first years; for after the grades and alignments are once fixed and approved by the county commissioners it will be but the work of a few years to cut and fill to the grades adopted and to make the necessary changes in the location of the road itself.

"We are to decide in many, very many, instances whether for all time the public shall be compelled to go hundreds of yards in extra travel—and miles, it may be—in order to preserve intact Mr. Johnson's calf pasture, or Mr. Bilkin's pig pen or potato patch, or whether it were better to

recommend at once condemnation of some small enclosure, or a large one if need be, in order that a road may be placed for the convenience of the public where it rightfully belongs.

"We are to use our knowledge of the general topography of the state in the matter of fixing the position and general direction of the principal roads, having regard to the coincidence of the same from county to county, so that finally our great state shall have what nature fitted her for,—the grandest system of roads in America.

"In many other states there is great difficulty in the matter of drainage, because of the flatness of the general surface; we have difficulty here in this thing only because of the ignorance of the average road builder. It is no fault of the topography.

"In other states also much difficulty is experienced in the matter of surface material, because of the unsuitableness of the average soil for road-beds. We have difficulty on the same line only because the average road builder seems not to have seen that almost any class of earth or other material in Montana will make a good road if only it be properly surfaced and drained.

"I suggest for your thought and discussion the following topics, that if their importance shall warrant they may be given to the proper committee or otherwise be brought before the convention, as shall seem wisest to you:

"(1.) Organization and order of business. (2.) Blanks to conform to the new laws. (3) Road oversight. (4.) Apportionment of work, with reference to county as a whole. (5.) Road machinery—what will be most economical and effectual implements? (6.) Matter of records—what is the best form of notes and plat?"

Hon. Fred Whiteside then took the chair and Paul S. A. Bickel acted as secretary.

Preliminary to the work of the convention the Chairman appointed the following committees:

Organization—H. B. Davis, F. H. Ray, Lewis Penwell, E. Beach, E. M. Wardwell, Ed. S. Bond, J. W. Wade.

Blanks to Conform to New Laws—Lewis Penwell, H. S. Hyatt, A. L. Jaqueth, J. W. Wade, Lee Word.

Manner of Utilizing Road-tax Workers—J. Larson, H. C. Freeman, William H. Risk.

Road Oversight and Information—Albert S. Hovey, H. B. Davis, Charles Helmick.

Apportionment of Road Work—William Muth, A. L. Jaqueth, A. E. Cumming.

Road Machinery—J. W. Wade, H. B. Davis, H. C. Freeman.

Plats and Records—J. S. Keerl, Finlay McRae, T. T. Baker.

Grades and Drains—H. B. Davis, A. L. Jaqueth, George K. Reeder.

Surveyor' Accounts with County—Keerl, Benjamin, Hyatt.

Legislation—Lewis Penwell, George Bruffy, Lee Word, F. H. Ray, J. S. Keerl.

The appointment of the committees completed the work of the morning, and an adjournment was taken until 2 P.M.

At 2 P.M. the meeting was called to order by A. E. Cumming, chair-

man; A. S. Hovey, secretary. A programme was laid out for the evening session, which was to be the most important of the convention. There was some informal discussion, but the principal topics were laid over until evening.

The Secretary reviewed the proceedings of the Montana Society of Engineers in the matter of county surveyors and road laws. This matter was first taken up by the Society at its annual meeting on January 14, 1893, at which time, on motion of Mr. J. S. Keerl, a committee of three, consisting of Messrs. Wheeler, Page, and Jones, was appointed to prepare a memorial to present to the Legislature, and to draft suitable bills regulating the compensation of county surveyors. The bill was not prepared in time for presentation to the Legislature during that session. The matter was again resumed by the Society, on October 13, 1894, and, through the untiring efforts of Messrs. E. R. McNeill, F. P. Gutelius, and Mr. Ray, of the Good Roads Association, House Bills Nos. 356 and 124 were finally passed by the Legislature in 1895. These bills, however, were very dissimilar to the bills as originally framed by the Society. The proceedings mentioned are printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, vol. xii, pages 108, 169, 276; vol. xiii, pages 100, 115; vol. xiv, pages 9, 13, 37, 64, 67.

At the annual meeting of the Society, held at Great Falls, January 9, 1897, it was considered advisable for the Society to make another effort to obtain proper legislation upon the Road Laws and County Surveyors' bill, and a committee of six was appointed, as follows: T. T. Baker, E. R. McNeill, P. S. A. Bickel, C. M. Thorpe, A. W. Mahon, and H. B. Davis, all being county surveyors except Mr. Bickel, an ex-county surveyor just retired. Through the efforts of this committee, House Bill No. 266, defining the powers and duties of county surveyors, and abolishing the office of road supervisor, was passed. (This bill was published in full in the JOURNAL, in vol. xviii, Proceedings, page 44.) House Bill No. 280, relating to the levy, collection, and disposition of road-taxes, was also passed. Both bills were passed substantially as framed by the Society, except House Bill No. 266, which changed the salary clause by making it the limit to be allowed the county surveyor in the different class counties, allowing the county surveyor a per diem of $5, and cutting off any provision for the payment of actual traveling expenses. The laws were passed to take effect as soon as passed. The Constitution of the state provides that no salary or emolument of a county official shall be changed during his term of office. According to good legal authority, the original per diem of $7 will hold during the present term, but in the next term of office the new law will take effect, viz: $5 per day, without allowance for traveling expenses. In many instances a single county in this state is larger than some of the Eastern States, and the traveling expenses will be frequently larger than the per diem. The future county surveyor will be obliged to devote his time, for the improvement of his county, for almost no compensation.

In view of complications, already commencing, the Society advised a convention of the county surveyors. After considerable discussion, the meeting adjourned to meet in Court Room No. 1 of the District Court, at 8 P.M.

EVENING SESSION.

The meeting was called to order at 8 P.M., March 30, Mr. Frederick Whiteside in the chair; Paul S. A. Bickel, secretary.

The meeting was an open one for all interested in the subject of good roads, and, as in the morning session, a number of well-known Helena wheelmen were present. Among the county officials present were two commissioners from Silver Bow county, two from Lewis and Clarke, and several others, including the full board from Broadwater county.

House Bill No. 280 was read, as follows:

HOUSE BILL NO. 280.

An act amending Sections 2640, 2642, 2643, 2680 of the Political Code, relating to the levy, collection, and disposition of road-taxes.

Be it enacted by the Legislative Assembly of the state of Montana:

SECTION 1. Section 2640 of the Political Code is hereby amended so as to read as follows: Section 2640. There must be levied out and collected on all taxable property in the county not less than one mill nor more than two mills on the dollar for road purposes; also a special road-tax of $3 on each able-bodied man over the age of twenty-one years, and under the age of forty-five years, residing in each road district, provided that any person liable for said special road-tax may elect to perform one day's labor, either in person or by another, on the public roads, under the proper officer as herein provided, in lieu of the payment of the said $3. Said special road-tax shall be due and payable to the county assessor after October the 1st of each year, unless one day's labor of eight hours has been performed in lieu thereof, as provided by law; and the county assessor shall collect such special road-tax on or before December the 1st of each year, in the manner provided by law, providing for the collection of poll-tax. All special road-taxes collected by him must be paid to the county treasurer monthly, and be placed to the credit of the county road fund of the road districts in which the same is collected. The county surveyor of each district shall, on or before the first day of October of each year, deliver or mail to the county assessor a list of the names of all male persons in each road district who are required to work said special road-tax for the year and who have failed to work out the same. Any person whose special road-tax is unworked by October the 1st of each year shall pay $3 to the assessor, as provided by law.

SEC. 2. Section 2642 is hereby amended so as to read as follows: Section 2642. Every person liable for said special road-tax who performs in person the one day's labor in lieu thereof shall receive a receipt for the sum of $3, signed by the county surveyor, which shall be a sufficient receipt for said special road-tax.

SEC. 3. Section 2680 is hereby amended so as to read as follows: Section 2680. If any person required to pay the special road-tax mentioned in preceding sections of this chapter has no property subject to taxation, and does not elect to work out said special tax as therein provided, the county assessor must collect the same at the time of making the assessment. If it be not paid at the time, and the person owing the same is in the employment of any other person, the assessor must deliver to the employer a written notice, stating the amount of tax owing by such employe (naming him), and from the time of receiving such notice said

employer is liable to pay said tax, provided that any money is then due or shall become due such employe from each employer before the time for the payment of general taxes, and the employer may deduct the same from any amount so due each employe.

SEC. 4. All acts and parts of acts in conflict with this act are hereby repealed.

Approved March 4, 1897, at 6.50 o'clock P.M.

ROBERT B. SMITH, *Governor.*

House Bill No. 266 (published in full in JOURNAL, vol. xviii, page 44) was then read.

Mr. Lewis Penwell, chairman of the Committee on Blanks to Conform to the New Law, introduced the following blanks: Order for supplies, receipt for road-tax work, affidavit of posting.

A paper from M. S. Parker, of Great Falls, entitled "The New Road Law of Montana," was then read and discussed.

Hon. Lewis Penwell, attorney-at-law, chairman of the Committee on Legislation, submitted the following opinion:

"If the new law, so far as compensation is concerned, is sustained by the courts, all county surveyors will receive $5 per day, up to the maximum, for all work performed, whether the said work is of a professional nature or upon roads. There is, however, a very serious doubt as to whether the new law, as regards compensation, can be sustained. The office of the county surveyor is a constitutional office, and accordingly the compensation of the incumbent of this office cannot be increased or diminished during his term of office. The duties, however, can be increased. At the time these county surveyors were elected the law stated that they should be paid for professional work only; the new law provides that they shall be paid for other work, thus altering their compensation after they have been elected to office. If this view of the matter were sustained by the courts, they would be entitled to $7 per day for professional services rendered under the old law, and would be required to perform the additional services imposed upon them by the new law, but without any additional compensation. This is the view now held by Attorney-General Nolan. Probably the way the matter stands now, if he were called upon by some board of county commissioners within this state for a ruling as to whether or not they would allow compensation to county surveyors for road work, he would hold that the said county surveyors were not entitled thereto. His suggestion is that such steps be taken as may be necessary to bring the matter before the courts immediately, and get the same finally disposed of.

"I will state further that Mr. Sanders and myself have given the matter some little consideration, and are constrained to differ with the Attorney-General, and believe that if the matter were taken into the courts it would be finally decided that the present county surveyors would be entitled to $5 per day, up to the maximum, for all services rendered, whether professional or otherwise."

By request of Mr. Beach, Section 2759 of the Political Code was read.

It was decided to bring the question before the courts, if possible.

J. S. Keerl, chairman of the Committee on Surveyors' Accounts with County, submitted the following report, which was adopted:

"The question of the location and construction of highway roads, in our opinion, should be surrounded by the same general features and considerations which govern the location, construction, and maintenance of railroads. The question of proper location should be governed by topographic features, and desirable alignment and grades and the stability of construction, which, co-related, have their bearings, should be recognized the same as upon railroad location and construction. With these views, we believe that to properly locate, construct, and maintain our public highways an organization should be perfected somewhat similar, or at least based upon those principles which surround the construction of railroads and other similar engineering works. The new law (which is entitled House bill No. 266,) passed by the Fifth Legislative Assembly of Montana, to be properly enforced and carried to a successful conclusion, we believe, should recognize the county surveyor as occupying a position similar to that of division engineer in charge of 100 miles of line upon a railroad construction, and that the road managers, which he will appoint, and as provided by the bill, fill a relative position to that of resident engineers upon railroad construction, who have charge of (say) 10 miles of line, and that, carrying forward the comparison, the resident engineers reporting to the division engineer all estimates, accounts, requisitions, etc., and the road managers reporting to the county surveyor, and thus recognizing that the county surveyor's office is the headquarters of the system which receives, collects, and distributes all information relative to the laying out, construction, and maintenance of the public highways. With these accounts, data, etc., and thus centrally located, the county surveyor is placed in a position where he can fittingly and thoroughly submit his report to the board of county commissioners, which board fills a position similar to that of the chief engineer of a railroad or its board of directors.

"Your committee have interpreted their duties as merely applying to suggesting a method of accounts, and not as regards detailing what accounts are necessary or in what form they should be presented, as they believe this would more properly belong to the 'Committee on Blanks to Conform to the New Law,' which report your honorable body have discussed fully."

The report of the committee was followed by an interesting discussion.

The Committee on Road Machinery, composed of J. W. Wade, H. C. Freeman, and H. B. Davis, recommended the use of improved road-making machinery wherever practicable. The committee believed that economy as well as improved roads would result from extensive and judicious use of machinery.

Mr. Wade stated that his county (Lewis and Clarke) had an Austin road machine, and that it would be used on all roads where it was practicable.

County Surveyor Thorpe.—The Austin machine makes the grade about 2½ feet above the bottom of the ditches, and we consider it a great saving of labor. We also use it largely for smoothing the grades.

County Surveyor Davis.—Three-fourths of the roads constructed by road supervisors in my county have no grades. The plowing has been done so near the wagon-tracks that the roadbed has to be filled in even before the freshets come.

COUNTY SURVEYOR WADE.—The advantage of this road machine is that it does not move any ground that is not put in the roadbed, and it leaves the waterways solid. It can be placed at such an angle as to plow 4 inches wide, or greater widths as desired. It has a swinging motion, and shaves off the earth.

Discussions by Messrs. Thorpe and Wardwell and others followed. Some of the speakers apparently did not favor the road machine.

Mr. Wardwell moved that a Committee upon Resolutions be appointed, and the chairman appointed Messrs. Muth, Wardwell, and Bradford, who presented the following resolutions:

WHEREAS, The new road law is very largely in the nature of an experiment; and

WHEREAS, Its provisions seek to obtain better results than under the old law, with the funds at the command of the different counties; and

WHEREAS, It is expedient that the law be given a full and fair trial; therefore be it

Resolved, That the county surveyors and boards of county commissioners of the different counties be called upon to use every endeavor to make a success of the said law by using special personal efforts to inaugurate a system of roads that will be a credit to each and every county and to the state, and to see that the funds of the counties are economically and judicially applied.

On motion of Mr. Wade, the convention adjourned until 2 o'clock P.M., March 31.

AFTERNOON SESSION.

The meeting was called to order at 2 P.M., Mr. F. Whiteside in the chair; Paul S. A. Bickel, secretary.

A discussion ensued upon plats and records, and the committee was given more time in which to report.

The county surveyors were unanimous in the opinion that all records and blanks should be uniform throughout their offices in Montana. The Committee on Blanks will not complete its work for several weeks.

A discussion on grades and drains, led by J. S. Keerl, of Helena, and E. M. Wardwell, was one of the most interesting features of the afternoon session. It practically ended the work of the convention, although, after adjournment, the sub-committee on plats, records, and blanks, consisting of Messrs. Paul S. A. Bickel, C. M. Thorpe, and T. T. Baker, J. S. Keerl, E. M. Wardwell, and others interested, met with the committee, which will report later to the Montana Society of Engineers.

The meeting was a successful one, and will, it is believed, result in better roads for the state.

It was moved and seconded that the Secretary use his influence to secure as full a publication as possible of the proceedings of the convention. Carried.

MR. KEERL.—I move that a vote of thanks be tendered to the county commissioners for their kindness in opening to us the court room; also, to the president and other officers, who so patriotically performed their duties; also, to the press. Carried.

A motion to adjourn was carried.

A. S. HOVEY, *Secretary*

The regular monthly meeting of the Society was held in the Merchants' National Bank Building, in Helena, on September 11, 1897. President C. W. Goodale arrived from his home in Butte just in time to call the meeting to order at the usual hour of 8 P.M. The fore part of the evening was devoted to business. Under the head of new business the President appointed Messrs. F. L. Sizer, of Helena, John Herron, of Marysville, and Elliott H. Wilson, of Butte, as a committee to nominate officers for the ensuing year. The Society voted to unite with the Society of Montana Pioneers in ordering from the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES 500 copies of the memoirs of the late Col. de Lacy. The subjects discussed were mining operations, tunnel rights, and the action of mineral in the water of mines upon the pumps and pipes. Mr. Goodale stated that after a considerable amount of experimenting he has succeeded in partially obviating the difficulty by treating the water before entering the pipes.

Members will find a complete set of the JOURNAL, all bound, in the Butte Public Library; also in the Helena Public Library, with the exception of Vol. No. 1, these libraries having obtained the early volumes by purchase. Three other libraries have incomplete sets. Mr. C. W. Goodale will endeavor to complete a set of the JOURNAL for the School of Mines, at Butte. The Secretary's donation of Vol. No. 1 completes the Society's set. All are bound, five volumes having been bound recently. Messrs. Sizer and Neustadter have contributed JOURNALS for filing in the public libraries.

A. S. HOVEY, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SEPTEMBER 3, 1897.—Called to order at 8.30 P.M. by President Molera.

The minutes of the last regular meeting were read and approved.

Mr. John Richards, past-president, read the paper of the evening on the subject of "Hydraulic Rams," which was discussed.

Adjourned.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Club of Cleveland.

MEETING of the Civil Engineers' Club of Cleveland, in the rooms of the Club, Case Library Building, Tuesday evening, September 14, 1897, President Ritchie in the chair. Present, 24 members and 3 visitors.

Secretary Coburn being absent, Mr. A. Lincoln Hyde was chosen secretary *pro tem.*

The minutes of the last meeting were read and approved.

Messrs. W. P. Brown and S. J. Baker were appointed tellers to canvass the ballots for the election of new members.

The Executive Board reported the approval for active membership of Messrs. H. E. Andrews and T. M. Brown.

The resignation of the vice-president, Mr. Clarence M. Barber, was read, and on motion it was voted that it be accepted.

A letter from Mrs. Royal Gurley was read by the president, and the following resolutions were offered by the committee appointed by the president:

As one by one we are called by the All-Wise Providence to relinquish our duties on this earth for those of promised peace and joy, so we now are called to mourn the death of our fellow-member, Royal Gurley, who, during his active lifetime, was connected with railroad work, mostly in the engineering department, and who, by his quiet, unobtrusive manner and upright dealing, was endeared to all his associates.

Resolved, That we extend to the bereaved widow and children of our deceased member our sincere and heartfelt sympathy.

Resolved, That this report and resolutions be placed upon the minutes of the Club and a copy of the same be sent to the widow of our deceased member.

HENRY C. THOMPSON,
AUG. MORDECAI,
JAMES MCINTYRE,
Committee.

On motion, these resolutions were unanimously adopted.

JAMES RITCHIE, *President.*

Attest: A. LINCOLN HYDE, *Secretary pro tem.*

Mr. William H. Searles read the paper of the evening on "The Consulting Engineer in Municipal Affairs." It was a very interesting paper, and called forth an unusually animated discussion, in which Messrs. Warner, Baker, Raynal, Johnston, Porter, McGeorge, and others took part.

Messrs. Charles Warren Comstock and John Wm. Easton were declared elected to active membership.

The meeting adjourned to partake of a light luncheon.

A. LINCOLN HYDE, *Secretary pro tem.*

Engineers' Club of St. Louis.

457TH MEETING, SEPTEMBER 15, 1897.—The meeting was held at 1600 Lucas place, at 8.30 P.M., with President Flad in the chair. Seventeen members and two visitors were present.

The minutes of the 456th regular meeting and the minutes of the 239th, 240th, and 241st meetings of the Executive Committee were read and approved.

The Executive Committee reported that an offer had been received for a duplicate set of 21 volumes of the Transactions of the American Society of Civil Engineers, and recommended that the offer be accepted. This recommendation was adopted by the Club. On motion of Mr. Crosby, duly seconded, it was voted that the money received from the sale of these Transactions be applied to the library fund.

Mr. Charles W. Hawkes and Mr. Henry Branch were proposed for membership, and their applications were referred to the Executive Committee.

The Secretary read a communication from the Western Society of Engineers inviting the Engineers' Club of St. Louis to participate in its

excursion to Niagara and Philadelphia. The thanks of the Club were voted the Western Society of Engineers for this invitation.

Mr. S. Bent Russell then gave an informal talk on repairs which had been done on the conduit and settling basins of the water works. Cracks had appeared, due to settlement and temperature changes, and the methods which had been adopted for repairing these cracks were illustrated. Lantern slides showing the construction of the conduit and basins were exhibited. In the discussion which followed, Mr. Crosby described the methods which had been employed for measuring the distortion of the arch in the Sudberry conduit.

The president then exhibited some lantern slides showing the launching of the new dredge-boat "Zeta," which took place at Grafton, August 25.

There being no further business, the meeting adjourned to another room, where lunch was served.

RICHARD McCULLOCH, *Secretary.*

Detroit Engineering Society.

DETROIT, MICH., SEPT. 17, 1897.—Regular monthly meeting held at the Hotel Ste. Claire, Vice-President Keep presiding, and 20 members and 5 visitors in attendance. Among the latter, by invitation, were Major M. B. Adams, U. S. A. Engineer, 9th and 11th Lighthouse Districts, and Alfred Noble, C. E., member Deep Waterways Engineer Commission.

On recommendation of the Executive Committee, Messrs. Joseph De Gurse, David Maxwell, Gouverneur Morris, George Parks, and George F. Parker were elected to resident membership.

The Society then listened to a paper by Mr. Frank M. Dunlap, on "The Machinery of the Poe Lock of the Ste. Mary's Falls Canal," at the close of which an extensive discussion was participated in by the members and visitors present.

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

Denver Society of Civil Engineers.

DENVER, COLO., SEPT. 14, 1897.—First regular meeting since the summer vacation called to order in Room 36, Jacobson Building, at 8 P.M., President Wilson in the chair, with several members present. Minutes of special meeting held June 1, 1897, were read and approved. No regular meeting held June 8, as the members of the Society were invited to attend in a body an evening session of the seventeenth annual convention of the American Water Works Association, at their headquarters, Albany Hotel.

After the canvass of the ballots, Messrs. John St. J. Lallie, of Denver, and Edwin H. Messiter, of Leadville, Colo., were declared elected to membership in the Society.

Sundry communications were read and ordered placed on file, the secretary being instructed to make the necessary replies in some cases.

Some of the members present reported having applications from persons desiring admission to the Society. Names to be presented at next meeting.

The librarian reported having found some supposed missing volumes from the library. The same, not being properly indexed, had been misplaced.

A paper, entitled "Colorado, a Sketch," by W. B. Lawson, was read by the secretary (owing to sickness, Mr. Lawson being unable to attend). The paper was a very interesting descriptive history of the State, and was well received by all present.

Mr. H. Breen stated that at the next meeting he would have some calculating machines on exhibition for discussion as to their merits, etc. Adjourned.

WALTER PEARL, *Secretary*.

Association of Engineering Societies.

Vol. XIX. | OCTOBER, 1897. | No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

458th Meeting, October 6, 1897.—The meeting was held at 1600 Lucas Place at 8 p.m., with President Flad in the chair. Nineteen members and five visitors were present.

The minutes of the 457th regular meeting and the 242d meeting of the Executive Committee were read and approved.

A letter was read from Mr. F. B. Maltby, Assistant United States Engineer in charge of the government works on the Osage River, inviting the club to visit the new dam now being built near Osage City. A motion was passed authorizing the Executive Committee to arrange for an excursion to this place.

The secretary announced that he had received applications for membership from Messrs. Wm. A. Hunicke, Vernon Baker, Henry H. Humphrey, George I. Bouton, E. C. Stolberg, Alwin Hofmann and Lee D. Fisher. These applications were referred to the Executive Committee.

The applications of Mr. Henry Branch, assistant engineer with Mr. Edward Flad, and Mr. Charles W. Hawkes, manager of the Springfield Boiler and Manufacturing Company, having been favorably reported upon by the Executive Committee, these gentlemen were balloted for and elected members of the club.

The paper of the evening, entitled "The Electrolysis of Caustic Soda," by Mr. A. L. McRae, was then read. In the absence of Mr. McRae, the paper was read by Mr. Miller. A process of manufacturing caustic soda from common salt by electrolytic methods was described and some figures given as to the cost of manufacture. This process has been used in England and Germany, but is not in use in this country. The paper described how the by-products, hydrogen and chlorine, may be utilized in heating the solution for concentration and in the manufacture of bleaching powder.

Following this paper, there were exhibited a number of lantern slides showing types of waterworks engines and sewage pumps. Mr. M. L. Holman explained the slides and pointed out the features of interest connected with each engine.

There being no further business, the meeting adjourned.

Richard McCulloch, *Secretary.*

459TH MEETING, OCTOBER 20, 1897.—The Club met at 8 P.M., at 1600 Lucas Place, with President Flad in the chair; twenty-four members and four visitors were present.

Before proceeding with its regular business the Club was entertained by the exhibition of a large number of stereopticon views, showing the various kinds of river improvement work used on the Mississippi and Missouri rivers. Views of dikes, levees, wing-dams and devices for protecting the banks of rivers were shown.

Mr. J. A. Ockerson pointed out the features of interest in the different views and explained the uses and methods of construction of the various dikes, levees, dams, etc. This collection of views belongs to Prof. D. L. Turner, of Harvard University, who kindly loaned it to the Club.

The minutes of the 458th meeting of the Club and the minutes of the 243d meeting of the Executive Committee were read and approved.

Messrs. Wm. A. Hunicke, Vernon Baker, Geo. I. Bouton, Henry H. Humphrey, E. C. Stolberg, A. Hoffman and L. D. Fisher were elected members.

Mr. Wm H. Bryan gave a short talk on "The Methods of Testing the Efficiency of a Heating System." He briefly explained the different systems of heating and reviewed the methods of testing heating systems that had been proposed by different writers.

Mr. Wm. Kent, of New York, and Messrs. Flad, Borden, Johnson and Kinealy took part in the discussion which followed.

J. H. KINEALY, *Secretary pro tem.*

Detroit Engineering Society.

DETROIT, MICH., OCTOBER 22, 1897.—The regular monthly meeting was held at the Hotel Ste. Claire, Friday evening, October 22, 1897, Vice-President Dow presiding, and twenty-one members and three visitors present.

The application of Mr. J. W. Schaub for membership by transfer from the Engineers' Club of St. Louis was favorably reported by the Executive Committee and he was elected to resident membership, with remission of initiation fee and of dues until January 1, 1898. The names of Messrs. C. W. Russell and T. F. McCrickett were proposed for membership and referred to the Executive Committee.

The Society then listened to "Some Notes on the Manufacture and Use of Aluminum," by Mr. Jesse M. Smith, which was read by the Secretary, a telegram from Mr. Smith regretting his absence being read by the Chairman. An extended discussion followed, after which the Society adjourned.

GARDNER S. WILLIAMS, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., OCTOBER 4, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 9 P.M. Present, eight members and one visitor, Mr. Loweth presiding. Mr. C. A. Alderman read a paper on the Chippewa Valley Electric Railway, an up-to-date system of about 22 miles nearly completed. Power is to be furnished for twenty years at $6

per H. P. Mr. Alderman also described the late trip of the Western Society of Engineers to Niagara and the Lehigh Valley, he being the only one of our members to take advantage of the general invitation to participate. The secretary was instructed to again thank the Western Society committee and express the hope that some future excursion of that Society might include a visit to the Twin Cities of the Northwest, where a welcome to many points of interest awaits its members.

Mr. Loweth exhibited the results of some paint tests—twenty-odd samples of black and more or less rust-roughened plates of sheet-iron, which had undergone six months' exposure to locomotive smoke while suspended from the roof of the Union Depot train-shed about 50 feet above the tracks. The iron plates, new and bright, had each received one coat of paint, and had been subjected to equal exposure. The red lead sample gave the best results; next came the white lead, followed by the iron oxides and an asphaltum, which were generally in much better condition than the graphites. An anti-rust specimen was the brownest spectacle of the lot.

C. L. ANNAN, *Secretary.*

The Civil Engineers' Club of Cleveland.

CASE LIBRARY BUILDING, CLEVELAND, O.—The October meeting of the Club was held in Case Library Tuesday evening, the 12th, President Ritchie in the chair. Present, 36 members and 16 visitors. In the absence of Secretary Coburn, W. H. Searles was elected Secretary *pro tem.* The minutes of the last meeting were read and approved. The applications for active membership of Mr. H. E. Andrews and Mr. T. M. Brown were presented and read. Nominations for the office of vice-president, which had been left vacant by the resignation of Mr. Clarence M. Barber, were announced to be in order. Mr. Frank C. Osborn was nominated by Mr. Searles, and on the motion of Prof. John W. Langley the nominations were closed and the Club proceeded to ballot. Messrs. Oldham and Searles were appointed tellers. Mr. Osborn was declared elected by unanimous vote. A paper entitled "The Mechanical Side of Steel Making" was then read by Mr. John MacGeorge. The paper dealt particularly with the latest methods and devices for mechanically charging open-hearth steel furnaces. A number of slides showing recent inventions in this line and the best devices of this kind now in use were cast upon a canvas and graphically described by Mr. MacGeorge. The subsequent discussion was begun by Mr. C. O. Palmer and participated in by Messrs. Johnson, Searles, Oldham, Raynal and Harman.

WM. H. SEARLES, *Secretary pro tem.*

Technical Society of the Pacific Coast.

SAN FRANCISCO, CAL., OCTOBER 1, 1897.—Regular meeting called to order at 8.30 P.M. by Past President Grunsky.

The minutes of the last regular meeting were read and approved.

Application for membership was made by Hiram R. Jones, chief engineer of the Selby Smelting and Lead Company, proposed by Louis Falkenau, George W. Dickie and Adolph Lietz.

Mr. W. H. Smyth read the paper of the evening, entitled "The His-

tory and Development of Hydraulic Dredging," which was discussed at length by Mr. A. B. Bowers and many members present.

It was moved that the reading of the paper on the subject of "An Old-time Level," announced for this meeting, be postponed until the next regular meeting. Seconded and carried.

Adjourned.

Otto von Geldern, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., September 15, 1897.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock p.m., President Dexter Brackett in the chair; one hundred and five members and visitors present.

The record of the last meeting was read and approved. Mr. Charles W. Hazelton was elected a member of the Society.

The Secretary read a letter from Mr. William B. Fuller resigning the office of Librarian of the Society on account of removal from Boston, and on motion the resignation was accepted. On motion of Mr. French it was voted to appoint a committee of three to report at the next meeting the names of candidates for Librarian. The President appointed as this committee Messrs. A. H. French, C. H. Swan and W. E. Foss.

Mr. Kimball for the committee appointed to prepare a memoir of Horace L. Eaton, submitted its report which was read.

The literary exercises of the evening consisted of an informal address by Mr. F. P. Stearns, describing the work now being built for the Metropolitan Water Supply of Massachusetts. The address was illustrated by a very complete set of lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

October 20, 1897.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock p.m., President Dexter Brackett in the chair; one hundred and nine members and visitors present.

The record of the last meeting was read and approved. Messrs. Edward S. Foster, James W. Martin, Will J. Sando and James L. Tighe were elected members of the Society.

The Treasurer was authorized, with the approval of the President to dispose of the railroad stock owned by the Society.

The committee appointed to nominate a Librarian submitted its report and upon a ballot being taken, Mr. Frank L. Fales was elected Librarian.

The thanks of the Society were voted to the officials of the Boston and Maine and of the Boston and Albany Railroad Companies and to the Metropolitan Water Board, for courtesies extended to the Society on the occasion of the excursion to Clinton on September 25. The thanks of the Society were also voted to the Boston officials of the Boston Terminal Company for courtesies shown the Society this afternoon.

Mr. Thomas H. Wiggin then read a paper, entitled "The Manufacture and Inspection of Cast Iron Pipe." The paper was illustrated by lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Horace Lafayette Eaton.—A Memoir.

By G. A. Kimball, Henry Manley and W. F. Learned, Committee of the Boston Society of Civil Engineers.

[Read September 15, 1897.]

Horace Lafayette Eaton was born in Boston, September 6, 1851. He was educated in its public schools, and entered the employ of the city of Boston in the City Engineer's Department in 1869. Amongst the works with which he was connected for the city of Boston are the High Service supply for South Boston and Dorchester, the Parker Hill reservoir, the Central Avenue bridge at Milton Lower Mills, Malden bridge and the Mystic Valley sewer. From 1884 to 1887 he was connected with the Park department and was engaged upon the Arnold Arboretum, Franklin and other parks.

In 1887 he was appointed City Engineer of Somerville, a position for which his experience of seventeen years in almost every kind of municipal engineering particularly fitted him, and by virtue of his office was Superintendent of Sewers, Engineer to the Water Board, and in charge of all engineering work for the city, including the new High Service System of waterworks, construction of sewers, and the Powder House Park. The latter was a work of art for which he was entitled to, and received, great credit.

Mr. Eaton was thoroughly honest and conscientious in every detail. He was peculiarly sensitive, especially when his plans, which were worked out with the greatest care, were criticised or changes suggested. He felt these suggestions or criticisms keenly, and brooded over them to such an extent as to cause him, sometimes, temporary illness.

In 1895 a few disaffected contractors and others circulated stories detrimental to Mr. Eaton's reputation for honesty, and finally influenced the City Council to order an investigation of his department, which was commenced on November 22. One hearing had been held, his enemies were allowed the greatest latitude in relating stories which were afterward proved false. The publication of these proceedings in the daily papers so worked upon Mr. Eaton's mind that, in a fit of temporary insanity, he took his own life, on November 23, 1895.

After his death, the investigation was continued by the City Council in a most thorough and searching manner. The report completely exonerated Mr. Eaton in every particular and severely censured every person who was in any way connected with the prosecution. The investigation proved that Mr. Eaton was a man of strict integrity, and it is the universal opinion of the citizens of Somerville that he performed his duties faithfully and that he was an honest, upright and painstaking official.

Mr. Eaton joined the Boston Society of Civil Engineers, March, 19, 1879, and served the Society as its secretary from December 20, 1882, to May 18, 1887. His faithful and conscientious service to this Society as its executive officer was thoroughly appreciated and the care and unsparing labor bestowed upon his work for it was characteristic of his whole life. He joined the American Society of Civil Engineers, February 1, 1893. Mr. Eaton leaves a wife and two daughters.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XIX. **NOVEMBER, 1897.** No. 5.

PROCEEDINGS.

The Detroit Engineering Society.

DETROIT, MICH., NOVEMBER 19, 1897.—The regular monthly meeting was held at the Hotel Ste. Claire, with President Jesse M. Smith presiding and thirty-two members and one visitor present.

Messrs. C. W. Russell and T. F. McCrickett were elected to resident membership.

The name of Mason L. Brown was proposed for membership and referred to the Executive Committee.

A proposed by-law was noticed as follows: "Persons not uniting with this Society within three months of the date of election to membership shall be considered as never having been proposed." Laid over to next regular meeting.

By request, the discussion of the paper on "Aluminum," presented at the last meeting, was continued by Messrs. Mattsson, Weil, Keep, Danzinger, Pettee, Cooley and Smith. The Society then listened to the paper of the evening, by Mr. W. J. Keep, on "Cast-iron under Impact," which was Pettee, Cooley and Smith. The Society then listened to the paper of the evening, by Mr. W. J. Keep, on "Cast-iron under Impact," which was discussed by Messrs. Cooley, Folger, McMath, Weil, Molitor, Smith, Dow and Keep.

A paper for the next meeting, on "Ornamental Marbles," by W. M. Courtis, was announced, after which the Society adjourned.

GARDNER S. WILLIAMS, *Secretary.*

DETROIT, MICH., NOVEMBER 19, 1897.—A meeting of the Executive Committee of the Detroit Engineering Society was held at the Hotel Ste. Claire. Present, Messrs. Smith, Keep, Hinchman, Pope and Williams. The fourth quarterly assessment of the Association of Engineering Societies, amounting to $23.75, was ordered paid. The applications for resident membership of Messrs. C. W. Russell and T. F. McCrickett were endorsed, and it was voted to extend to Alfred Noble, C. E., the invitation of the Society to avail himself of a member's privileges during his engagements in Detroit. Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., November 1, 1897.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 p.m. Present, 7 members. Minutes of previous meeting read. Mr. Woodman, chairman of Committee on Membership, presented a table showing the requirements for membership in various branches of the Association of Engineering Societies, and the committee was requested to report at the next regular meeting recommendations as to membership and name. The Secretary read a paper on "Paint Tests," by Mr. W. J. Wilgus, and a vote of thanks for the same was accorded Mr. Wilgus. President Hilgard then read a few notes on "The Development of Water Powers." At Telluride, Col., a head of 900 feet is utilized, and power is transmitted to the various mining camps a maximum distance of 14 miles. Even at a cost of $120 per horse-power per annum, a saving of 25 per cent. over the old coal methods is claimed, and the electric light appears quite generally in the miner's cabin. Water power is now transmitted 50 miles into Salt Lake City and 20 miles into Butte, with the possibility of greater power being brought in from a distance of 60 miles. Mr. Estabrook spoke of the relative cost of steam and water power at the Minneapolis Mills.

C. L. Annan, *Secretary.*

Conditions of Membership in the Engineering Societies, April, 1897.

	Civil	Me-chan'l	Min-ing	Elec-trical	Mili-tary	Geol-ogists	Archi-tects	Sur-vey'rs	General Interest in Science	Years of Pract. alone	College Degree & Years Practice
Boston	*	*	*	*	*	*	*	*			
Virginia	*	*	*	*		*	*				
Cleveland	*	*	*	*	*	*	*	*	*	3	* and 1
St. Louis	*	*	*	*	*	*			*		
St. Paul	*	*	*			*				5	* and 3
Minneapolis	*	*	*	*	*	*					
Denver	*	*	*	*				*		2	* and 2
Montana	*	*	*		*	*	*		*	5	*
Pacific Coast	*	*	*	*	*		*	*		5	* and 3

* An asterisk indicates that a person of the class indicated by the heading of the column is eligible to membership in the Society whose name appears at the end of the line.

Technical Society of the Pacific Coast.

November 5, 1897.—Regular meeting called to order at 8.30 p.m. by Prof. Frank Soulé.

The minutes of the last regular meeting were read and approved.

The following were elected to membership:

1. Hiram R. Jones, chief engineer of the Selby Smelting Works.
2. P. R. Lamar, chief engineer of the Golden Crown Mining Company.

The Secretary read a paper written by Mr. H. Clay Kellogg, entitled "Pipe Line No. 2, and the Lands Irrigated under the Same at Corona, Riverside County, Cal.," which was discussed.

The Secretary read a paper, entitled "A Level of Ye Olden Time," which was discussed by a paper written and read by Mr. Adolf Lietz.

Adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

460th Meeting, November 3, 1897.—The Club met at 8 p.m., at 1600 Lucas Place, with President Flad in the chair. Thirty-three members and three visitors were present.

The minutes of the 459th meeting of the Club and the 244th meeting of the Executive Committee were read and approved.

The President announced that Mr. T. A. Mysenberg had presented to the Club several volumes of *London Engineering*. The thanks of the Club were voted to Mr. Mysenberg for this donation.

The paper of the evening, by Mr. F. F. Harrington, entitled "Underground Conduits in St. Louis," was then read. A short history of the legislation on this subject was given, and the requirements of the final ordinance were set forth. The rules adopted by the Board of Public Improvements in granting permits and the agreements between the different electric lighting companies were given in detail. Then followed a description of the different systems and conduits which have been adopted. A large number of working drawings and specimens of ducts were exhibited. Lantern slides, showing views taken during the construction, were used in explaining the methods adopted.

The discussion which followed the reading of this paper was participated in by Messrs. Wagner, Abbot, Niper, Reber and McCulloch.

There being no further business, the meeting adjourned to another room, where lunch was served.

Richard McCulloch, *Secretary.*

461st Meeting, November 18, 1897.—The Club met at 8 p.m., at 1600 Lucas Place, with President Flad in the chair. Twenty-six members and one visitor were present.

The minutes of the 460th meeting of the Club and the 245th meeting of the Executive Committee were read and approved.

The application for membership of Mr. Ferdinand Schwerdtmann, superintendent of the Wagner Electric Manufacturing Company, having been favorably reported by the Executive Committee, this gentleman was balloted for and elected a member of the Club.

The President stated that Col. E. D. Meier had presented to the library two volumes of the "Transactions of the Institute of Mining Engineers." The thanks of the Club were voted Colonel Meier for this donation.

Mr. J. A. Ockerson made a motion that a nominating committee consisting of Messrs. B. L. Crosby, Wm. Wise, L. P. Butler, W. G. Comber and F. F. Harrington be appointed to select for the Club a list of nominees for the several offices provided for in the Constitution, and to present the same at the next meeting.

Prof. J. B. Johnson then made an address on "The Results of a Recent Investigation of the Relative Strength of Wooden Beams and Columns in Large and Small Sizes." This investigation was conducted at the testing laboratory of Washington University for the Government Forestry Division. The large beams were of selected lumber, and were tested green. They were 18 to 24 feet in length, and were 8 inches by 12 inches in section. Eight small beams, 5 feet long and 4 inches square in cross-section, were made out of each large beam after it was broken. The beams were of oak, white pine, short leaf pine and long leaf pine. Tests were also made on large pine beams, which had been taken out of the Exposition Building after thirteen years of service. The average of these tests showed that the large beams had 92 per cent. of the strength of the small ones, and that the apparent elastic limit in the large beams was 97½ per cent. of that of the small ones.

Large columns showed a strength of 75 per cent. of small columns.

The discussion which followed was participated in by Messrs. Sterne, Kinealy, Borden, Crosby, Russell, Bouton, Flad and Ockerson.

The Executive Committee, having recommended that Prof. Calvin M. Woodward be elected an honorary member, a motion was made that the vote on this candidacy be postponed until next meeting, and that it be announced in the notice of the meeting, that such a vote would be taken. After some discussion this motion was carried.

There being no further business, the meeting adjourned.

Richard McCulloch, *Secretary.*

The Civil Engineers' Club of Cleveland.

The regular meeting of the Club was held in Case Library, on Tuesday evening, November 9, 1897. President Ritchie was in the chair. There were present 48 members and 9 visitors.

The minutes of the last meeting were read and approved.

Ballots were canvassed for the election to active membership of H. E. Andrews and T. M. Brown. Mr. James MacIntyre and Mr. Frank C. Osborn were appointed tellers.

The report of the regular meeting of the Executive Board was read and the application of L. B. Hoit for active membership recommended.

A communication was presented from Benjamin S. Hubbell, Secretary of the Cleveland Architectural Club, containing notice of their second annual exhibition, to be held November 15–27, and inviting the Club to visit the exhibition *en masse.*

It was moved by Mr. Warner that an evening be appointed by the Executive Board on which the Club could make the visit in a body, and that the invitation thereby be accepted and that thanks be rendered to the

Architectural Club for their kindness. Mr. W. H. Searles moved to amend that the Club appoint the evening, and suggested November 18. Mr. Warner thereupon withdrew his motion in favor of the amendment, which was then carried.

The paper of the evening, entitled "Visits to Some Scientific Institutions in Europe," was then presented by Edward W. Morley, Ph.D., LL.D.

The discussion which followed was participated in by Messrs. Warner, Raynal, Oldham, Miller and others.

The tellers reported H. E. Andrews and T. M. Brown as elected to active membership. The meeting adjourned. A light luncheon was served.

W. H. Searles, *Secretary pro tem.*

BRADLEY & POATES, ENGR'S N.Y.

Association of Engineering Societies.

Vol. XIX. | December, 1897. | No. 6.

PROCEEDINGS.

The Montana Society of Civil Engineers.

The Montana Society of Civil Engineers will hold its annual meeting in Butte, January 8th next. The date and place of the session was decided at the regular meeting of the Society which was held December 11, 1897, in the Merchants' National Bank building, Helena, Mont.

President C. W. Goodale, of Butte, presided at the meeting, which was well attended. The application for membership of Milo S. Ketchum, of Butte, was favorably considered, and the Secretary was instructed to send out the usual letter ballots.

The report of the Nominating Committee, F. L. Sizer, John Heron and E. H. Wilson, was received and approved. The following is the list of candidates selected: James M. Page, of Twin Bridges, President; Maurice S. Parker, of Great Falls, First Vice-President; Forrest J. Smith, of Helena, Second Vice-President; Albert S. Hovey, of Helena, Secretary and Librarian; James S. Keerl, of Helena, Treasurer and member of the Board of Managers of the Association of Engineering Societies, and Edward R. McNeill, of Boulder, Trustee for three years.

The meeting at Butte next month promises to be largely attended. A Committee on Arrangements will be appointed by the President to arrange the details of the coming session.

Civil Engineers' Club of Cleveland.

Cleveland, December, 14, 1897.—The regular meeting of the Club was held in Case Library on Tuesday, December 14, at 7.45 P.M., President Ritchie in the chair. Present, forty-two members and ten visitors.

The minutes of the last meeting were read and approved.

The President appointed Messrs. L. Herman and A. A. Skeels tellers to canvass ballots, and on receiving their report in due form he declared Lehman Benjamin Hoit elected an active member of the Club.

The report of the Executive Board referred briefly to the death of Forrest A. Coburn, late Secretary of the Club, which occurred on December 1st inst., and recommended that suitable action be taken thereon.

The Board reported favorably upon the application of Stanley R. Greene for active membership, and his application was read by the Secretary.

The letter of resignation of Cecil L. Saunders, active member, was reported received. The Board would act upon this at its next session.

The Secretary announced the receipt of the following books and papers: Vol. XVIII of the Transactions of the American Society of Mechanical Engineers, from their Secretary, Prof. F. R. Hutton, of New York, a valuable contribution to our library; six numbers of "Water Supply and Irrigation Papers," 5-11, of the United States Geological Survey, from Mr. F. H. Newell, Washington, D. C., and the presidential address of Prof. Mansfield Merriman before the Society for Promotion of Engineering Education, August 20, 1896; also a paper by the same author, on Probability of Hit when Probable Error of Aim is Known, in Artillery Practice."

The President appointed J. R. Richardson, C. W. Hopkinson and Jos. C. B. Beardsley a committee to prepare suitable resolutions upon the death of Mr. Coburn.

The President gave notice that, the office of Secretary being vacant, an election by ballot would be held at the next regular meeting to fill said vacancy for the unexpired term, and that nominations were now in order.

Mr. Osborn nominated W. H. Searles. This was seconded by Mr. Oldham, and there were no other nominations made.

The Secretary announced that, in accordance with the calendar of the Club, there would be a semi-monthly meeting on the 28th of December, at which time a paper by Mr. C. G. Force was expected. Mr. Porter, for the Program Committee, begged leave to state that, as Mr. Force would not be able to have his paper ready by that date, Mr. Newman would present his paper, postponed from the 9th of November last.

The Club then listened to the paper of the evening, on "Boilers," by Mr. John P. Johnston, active member. The author compared various types of boilers as adapted to different purposes, treated of boiler specifications, of the use and abuse of boilers in practice and of their possibilities in the future.

An animated discussion ensued, which was participated in by Messrs. Raynal, Oldham, Newman, Benjamin and Johnston. By invitation, Mr. C. A. Burwell addressed the Club on the same topic.

On motion, the President was empowered to sign the records of previous meetings left unsigned by Secretary Coburn.

The Club adjourned at 9.30 to partake of a light luncheon.

Wm. H. Searles, *Secretary pro tem.*

Cleveland, December 28, 1897.—Special meeting held in Case Library.

The meeting was called to order at 8 o'clock p.m.; President Ritchie in the chair; present, thirty-five members and six visitors.

Minutes of the last meeting were read and approved.

The letter of resignation of Mr. Wm. C. Jewett as Director, on account of his removal from town, was read, and, on motion, his resignation was accepted. Nominations for Director, to fill the vacancy, being in order, Mr. Coffin nominated Mr. Joseph R. Oldham; Mr. Gobeille nominated

Mr. August A. Honsberg, and the nominations were closed. Ballots to be canvassed at the next regular meeting.

The paper of the evening, on "Construction of Ships for Service on the Great Lakes," was then read by Mr. Richard L. Newman, active member.

The paper was illustrated by numerous drawings and charts, and treated of the methods by which modern ships are given greater strength in cross-section without increasing the weight or depth, thus permitting the design of vessels of much greater length and tonnage than were thought possible a few years ago. The proper location of the machinery, as affecting the strength of the hull, was considered.

The discussion was by Messrs. Oldham, Raynal, Cowles, Johnston and Ritchie, members of the Club, and by Capt. John F. Tuttle and Mr. John W. Seaver, visitors. Adjourned. A light luncheon was served.

WM. H. SEARLES, *Secretary pro tem.*

Boston Society of Civil Engineers.

NOVEMBER 17, 1897.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock, P.M.; President Dexter Brackett in the chair, 127 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Thomas S. Burr, Edward F. Miller and Charles G. Waitt were elected members of the Society.

The President announced the death of Thomas Doane, a past president of the Society, which occurred on October 22, 1897, and, on motion, the President was requested to appoint a committee to prepare a memoir. The committee appointed consists of Messrs. Desmond Fitzgerald, C. Frank Allen and Charles A. Pearson.

The thanks of the Society were voted to the Boston Transit Commission for courtesies extended this afternoon, on the occasion of the visit to the subway.

Mr. Frank A. Barbour then read the paper of the evening, entitled "The Strength of Sewer Pipe and the Actual Earth Pressure in the Trench." The paper was very fully discussed by Messrs. F. H. Snow, T. H. Barnes, Henry Manley and F. C. Coffin, of the Society, and by Messrs. J. A. Baldwin and B. W. Robinson, of Akron, Ohio; E. W. Buel, of the Barberton, Ohio; E. B. Winslow, of Portland, Me.; G. C. Dunn, of Boston, and H. P. Eddy, of Worcester, Mass. Adjourned.

S. E. TINKHAM, *Secretary.*

DECEMBER 15, 1897.—A regular meeting of the Society was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock P.M.; Vice-President C. Frank Allen in the chair, 82 members and visitors present.

The record of the last meeting was read and approved.

The death of William C. Hall, a member of the Society, was announced, and the President was requested to appoint a committee to prepare a memoir. The President has named as members of that committee Messrs. N. S. Brock, B. T. Wheeler and J. L. Woodfall.

Mr. Frank P. McKibben was then introduced, and read a paper, entitled "The Erection of Metallic Bridges." The paper was very fully illustrated by lantern slides. The discussion which followed the reading of the paper was participated in by Messrs. J. P. Snow, B. W. Guppy, H. J. Howe and H. K. Higgins. Adjourned.

S. E. TINKHAM, *Secretary*.

Engineers' Club of St. Louis.

463D MEETING, DECEMBER 15, 1897.—The annual dinner was held at the Southern Hotel at 8.30 P.M. After the dinner had been served, the meeting was called to order by President Flad. There were thirty-nine members and six visitors present. The President announced that the result of the letter ballot for officers for 1898 was as follows: President, Wm. H. Bryan; Vice-President, B. H. Colby; Secretary, Richard McCulloch; Treasurer, Thos. B. McMath; Librarian, E. J. Jolley; Directors, Edward Flad, John A. Laird. Members of the Board of Managers of the Association of Engineering Societies, J. B. Johnson, Arthur Thatcher.

The proposed amendment to the constitution had been carried by a vote of 91 for the amendment and 8 against it.

President Flad then addressed the Club, giving a *résumé* of the work of the year. He then introduced the new President, Mr. Wm. H. Bryan, who presided during the remainder of the evening. Mr. Bryan made an address in taking the chair, in which he outlined some of the plans for the next year.

Col. E. D. Meier then responded to the toast, "The Engineer Socially Considered." He gave a humorous account of the origin of engineers and engineering, and advised engineers to devote more attention to the social side of life.

Mr. M. L. Holman responded to the toast, "Wanderings Abroad." He gave an account of a recent trip to Germany, his remarks being replete with humor and wisdom.

The toast of "Early Experiences" was responded to by Mr. Henry Branch. The ups and downs of the young engineer were the subject of his remarks.

Mr. F. A. Abbot then addressed the Club on the subject of "The Engineer as a Contractor." After remarking on the universal suspicion which seems to attach itself to the contractor, he prophesied the approach of a golden age, when all contractors would be engineers, and all extra work bills would be paid without question.

Informal remarks were then made by Prof. J. B. Johnson and Prof. C. M. Woodward, after which the meeting adjourned.

RICHARD MCCULLOCH, *Secretary*.

The Detroit Engineering Society.

DETROIT, MICH., DECEMBER 16, 1897.—The regular monthly meeting was held at the Hotel Ste. Claire, President Jesse M. Smith presiding, and thirty-five members and thirteen visitors present.

The paper of the evening was presented by Wm. M. Folger, Commander United States Navy, member American Society Mechanical Engineers,

on "American Armor for Vessels of War," and was extensively illustrated by photographs of results of armor tests. The paper elicited many questions from members, which were extensively considered by the author. The discussion was participated in by Messrs. Dunlap, Wilkes, Smith, Courtis, McMath, Field, Schaub, Williams and Dow.

The application of Mason L. Brown having been reported upon favorably by the Executive Committee, he was elected to resident membership.

An invitation was received from the Michigan Engineering Society to participate in the annual convention at Port Huron, December 28 to 30, 1897, and the Secretary instructed to extend the thanks of the Society for the courtesies. Four candidates were proposed for resident membership, and referred to the Executive Committee. The following, to be known as By-Law IV, was adopted:

"Persons proposed for membership who do not unite with the Society within six months of their election, shall be considered as never having been proposed, provided they shall be notified in writing of this By-Law at least thirty days before the termination of this period."

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*

MEETING of the Executive Committee held December 16, 1897. Four members present. Bills amounting to $12.70 for printing, Journals and postage were audited and ordered paid.

Application for membership and By-Law referred to committee at last meeting of the Society were approved and ordered reported.

Checks of form suited to the requirements of the constitution were ordered printed. The following was adopted:

Resolved, That all bills audited by this committee shall be endorsed by the chairman of the meeting at which they are audited.

Adjourned.

GARDNER S. WILLIAMS, *Secretary.*